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THESIS

AN ANALYSIS OF A PUFF DISPERSION
MODEL FOR A COASTAL REGION

by

Stephen K. Rinard

June 1982

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gradient, buoyant heat flux and maximum mixing depth have been considered. Model predicted pollutant concentrations have been compared to airborne sampled observations. The effect of coastal turbulence not observed by the single point meteorological measurements made onboard ship greatly affects the advection and diffusion of a plume as it moves onshore. Additional measurements/predictions particular to the coastal area will have to be incorporated into the model for it to accurately predict the onshore movement of pollutants.

An Analysis of a Puff Dispersion Model for a Coastal Region

by

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ABSTRACT

The Risø National Laboratory, Roskilde, Denmark, atmospheric puff dispersion model has been tested for an atmospheric-marine environment. This three-dimensional model simulates the release of Guassian pollutant puffs and predicts their concentration as they are diffused and advected downwind by a horizontally homogeneous, time-dependent wind. Atmospheric characteristics such as turbulence intensity, potential temperature gradient, buoyant heat flux and maximum mixing depth have been considered. Model predicted pollutant concentrations have been compared to airborne sampled observations. The effect of coastal turbulence not observed by the single point meteorological measurements made onboard ship greatly affects the advection and diffusion of a plume as it moves onshore. Additional measurements/predictions particular to the coastal area will have to be incorporated into the model for it to accurately predict the onshore movement of pollutants.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

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I. INTRODUCTION

The downwind transport and distribution of atmospheric pollutants from an isolated source over land or water has become an important environmental factor in today's society. The need to understand the distribution of smoke, unpleasant or potentially harmful foreign gases and perhaps radioactive debris from a nuclear powerplant accident are becoming more and more essential for industrial operations and construction planning. The dispersion of such atmospheric pollutants is commonly modeled by a standard Guassian plume model which computes one-hour average plume characteristics.

The Meteorology Section of the Risø National Laboratory, Roskilde, Denmark, has recently developed a puff model for prediction and simulation of atmospheric pollutant diffusion. The model considers individual puffs of pollutants with specific release rates that are advected by a horizontally homogeneous wind over a grid. The wind input may be either the measured wind from a single point, a spatial average or a wind simulation. The model simulates the instantaneous plume characteristics by adding a group of puffs, growing in size, as they advect with the wind. A Guassian plume model, on the other hand, provides a time

averaged concentration pattern based on a single time average wind vector. In the puff model, the plume advects with a time series of actual wind data. Thus, the puff model is able to predict time varying concentration distributions in actual changing wind conditions, making it an appropriate tool for dynamical computations of downwind dispersions of pollutants.

A basic comparison of a puff model simulation and a typical plume is illustrated in Fig. 1. Looking from above, the instantaneous behavior of a plume being advected from a source by the wind is shown. The outer cone-shaped contours represent the outer limit of the plume boundary and are identical in both Figs. 1 (A) and (B).

Fig. 1(A) shows an instantaneous depiction of an actual plume. The long-term average plume concentration is shown on the extreme right as a smooth curve with a maximum on the central axis. Also shown is the instantaneous plume concentration considered realistic but is of such a short time scale that it cannot be predicted or easily measured.

The puff model prediction is depicted in Fig. 1(B). The circles show the boundaries of individual puffs of pollutants released from the source. These puffs are advected

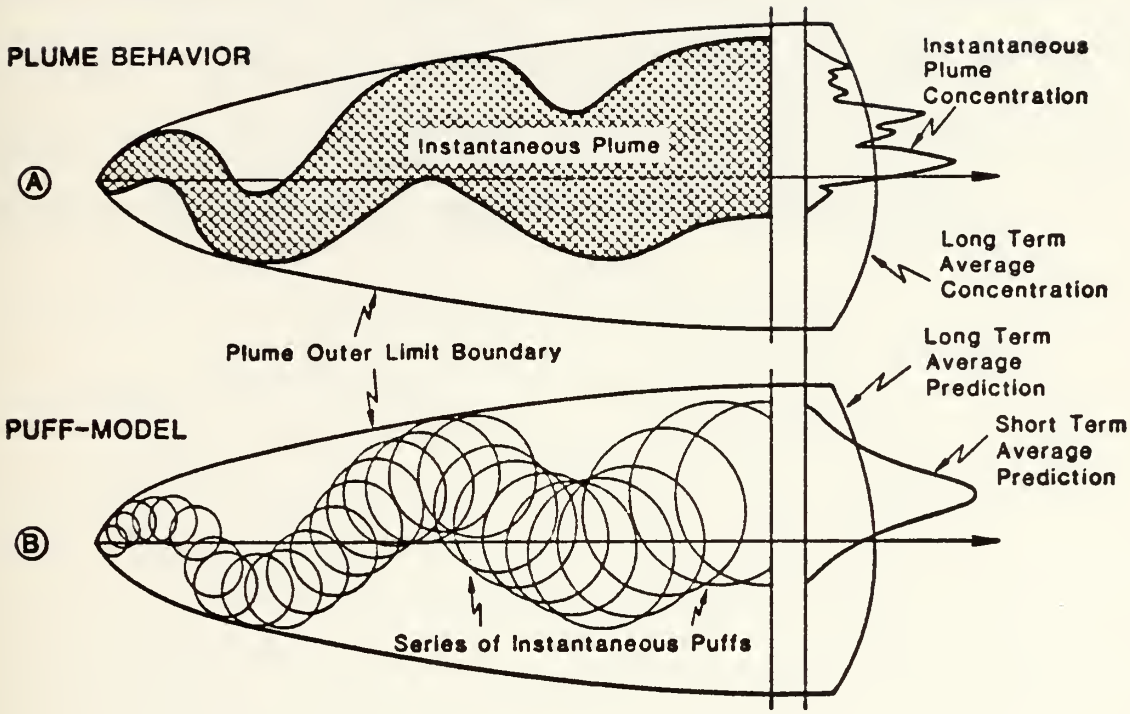


Figure 1. Instantaneous Behavior of a Typical Plume and a Series of Puffs from a Puff Model

and diffused downwind by a frequently updated wind. The long term average concentration prediction of the puff model is expected to be identical to the long term concentration of Fig. 1 (A). The short term average pollutant prediction, a Gaussian curve shown on the extreme right, is not completely realistic but is a reasonable approximation to the instantaneous plume concentration profile.

The purpose of this thesis is to evaluate and test the general characteristics and capabilities of the Risø puff model. The adjustable input data will be varied and predicted results for various input combinations compared. A preliminary comparison will also be made between predicted results and data collected from a coastal region using observed meteorological forcing data as model input.

II. RISØ PUFF MODEL

A. GENERAL CHARACTERISTICS

The Risø Puff Model is a three-dimensional computer model used for the prediction and/or simulation of the diffusion and advection of atmospheric pollutants. The puff model technique is to simulate a plume with Guassian shaped puffs with specified release rates within a specified grid. The initial size of the puffs is normally one meter in diameter although this can be easily adjusted. The amount of material in a puff is the release rate times the elapsed time between puffs. Therefore, a long elapsed time between puff releases results in a higher initial puff pollutant concentration than a short time interval. This should not normally be of concern if an adequate balance is maintained between grid size, advection speed and puff release rate.

The location of the puffs on the grid is determined by computing their movement for a finite time step using a measured wind field. The growth and buoyancy of the puffs are computed from simultaneous specifications of atmospheric turbulence intensity and stability and from buoyant heat

flux at the source. An inversion cap through which pollutants cannot pass and the source height where pollutants are released are variable and can easily be adjusted. Grid distances within the model may vary from meters to kilometers and time durations from seconds to hours are possible.

This puff model has the capability of monitoring a maximum of twenty-five sources of puffs and its grid may contain up to 100 puffs. A puff source can be located anywhere on the grid and have a unique release rate, start and stop of release time, and heat production. When the center of a puff moves outside the boundaries of the grid (either horizontally or vertically), that particular puff is dropped from memory. In this way the model does not store irrelevant puff information, thus keeping computer memory requirements to a minimum.

A variable to control the amount of reflection/absorption of the pollutant by the surface is easily adjusted in the puff model. Such a parameter is of great value both in actual dispersion problems and also for gaining understandings of the plume/surface relationship.

The model calculates the concentration at each grid point by summing the contributions from surrounding puffs

for each advection step. The grid concentrations can be allowed to accumulate or simply be updated with the latest instantaneous value. A minimum grid concentration of interest can be set to reduce computer run time by dropping concentrations too small to be of interest.

The output of the model contains periodic results of puff locations and concentrations as well as initial input verification. The time interval for the periodic results is adjusted by the input data. This recurrent lineprinter output contains:

- X-Y plane plots showing the position of the sources and of puffs inside the grid,
- X-Z plane plots of puff positions for evaluating plume rise for each vertical level of interest, and
- a table listing of the grid point concentrations for each level.

A computer drawn contour chart of the magnitudes of the pollutant concentrations is also available.

When considering distance between gridpoints (delta X,Y,Z), only spatial resolution and computer resources need be considered. Calculated concentration accuracy is not related to the grid-point separation. To insure that no essential information on individual puffs is "hidden" between grid points, the grid separation should be adjusted dependent upon the size of the puffs at the downwind distance of interest. Other specific model configuration considerations are described in the following sections. They are also discussed in more detail in the model behavior chapter.

B. WIND FIELD

Once a puff is released, it is advected based upon wind data measurements at a single point only, normally the release point. This limits the validity of the model to situations where the wind field and turbulence can be assumed to be horizonally homogeneous throughout the grid. It is therefore important to insure that the data obtained from such a single point measurement is representative of the wind structure for the whole area of interest.

The wind data are normally obtained in the form of a horizonal velocity time series. A vector sequence is formed

by averaging over a convenient interval. These data are read into the model after being segregated into turbulence classes as discussed in the next section.

C. TURBULENCE INTENSITY AND DIFFUSION

The growth/diffusion of a puff depends upon the turbulence intensity. To account for this growth, the puff model applies the theory for relative diffusion suggested by Smith and Hay (1961).

The turbulence intensity is defined to be the standard deviation (sigma) of the wind direction (in radians) squared. The sigma values are collected for the same short time periods as the wind speed measurements used to advect the puffs. Therefore, the intensity of the turbulence which governs the relative diffusion of the puffs, can be adjusted along with the the advecting wind speed after each time step, if conditions warrent.

A very low value of turbulence intensity (as 0.0002) represents a small standard deviation (0.9), normally a stable atmosphere and a weak puff dispersion/diffusion. As the atmosphere becomes more unstable, the turbulence intensity increases along with an increase of sigma values and plume dispersion/diffusion. While these characteristics are

resentative of turbulence over land, they can be applied to over water cases in a broad sense.

D. PLUME RISE

In the vertical direction, puff-rise can be accounted for by Briggs (1970) plume rise theory. In this case buoyancy is assumed to be conserved (adiabatic motion), and pressure forces, molecular viscosity and local density changes are considered small and are neglected. The rate at which a puff rises as it is advected downwind is a function of the buoyancy flux, wind speed, puff distance traveled and stability of the atmosphere. Plume rise is considered seperately for each individual puff.

E. REFLECTION

The interaction of the pollutant with the surface is adjustable and can be easily changed in the input data. Total reflection or absorption or a fraction between the two can be used.

F. LIMIT OF MIXING DEPTH

The effect of an atmospheric lid (inversion) can be applied in the model to limit the vertical movement of the pollutant. The model does not permit the plume to rise

above this cap. When a maximum mixing level is in effect, it acts to totally reflect the pollutants in the same manner as total reflection at the surface. This mixing cap would act as an inversion when the puff would be expected to grow much more readily in the horizonal than in the vertical direction.

III. DATA COLLECTION

An intensive field tracer study was performed during the fall of 1980 and winter of 1981 in the Santa Barbara Channel area of the California coast. The work was supported by the Bureau of Land Management (BLM) and performed by the Enviormental Physics Group of the Naval Postgraduate School (NPS) and AeroVironment Inc (AV), Los Angeles, CA. This study was designed to help validate and/or modify Gaussian dispersion models for coastal use and to build a data base for future model development. Air pollution models in current use have not been adequately validated for the over-water regime.

In the experiment, a tracer gas (SF_6) was released several miles offshore from the NPS Research Vessel (R/V) Acania. Ambient gas concentrations as low as 10 parts per trillion (PPT) were determined by an array of land based sensors, from a small boat and at various levels by an aircraft equipped with a continuous SF_6 analyser. A chart of the experimental area and locations of the various platforms is shown in Fig. 2.

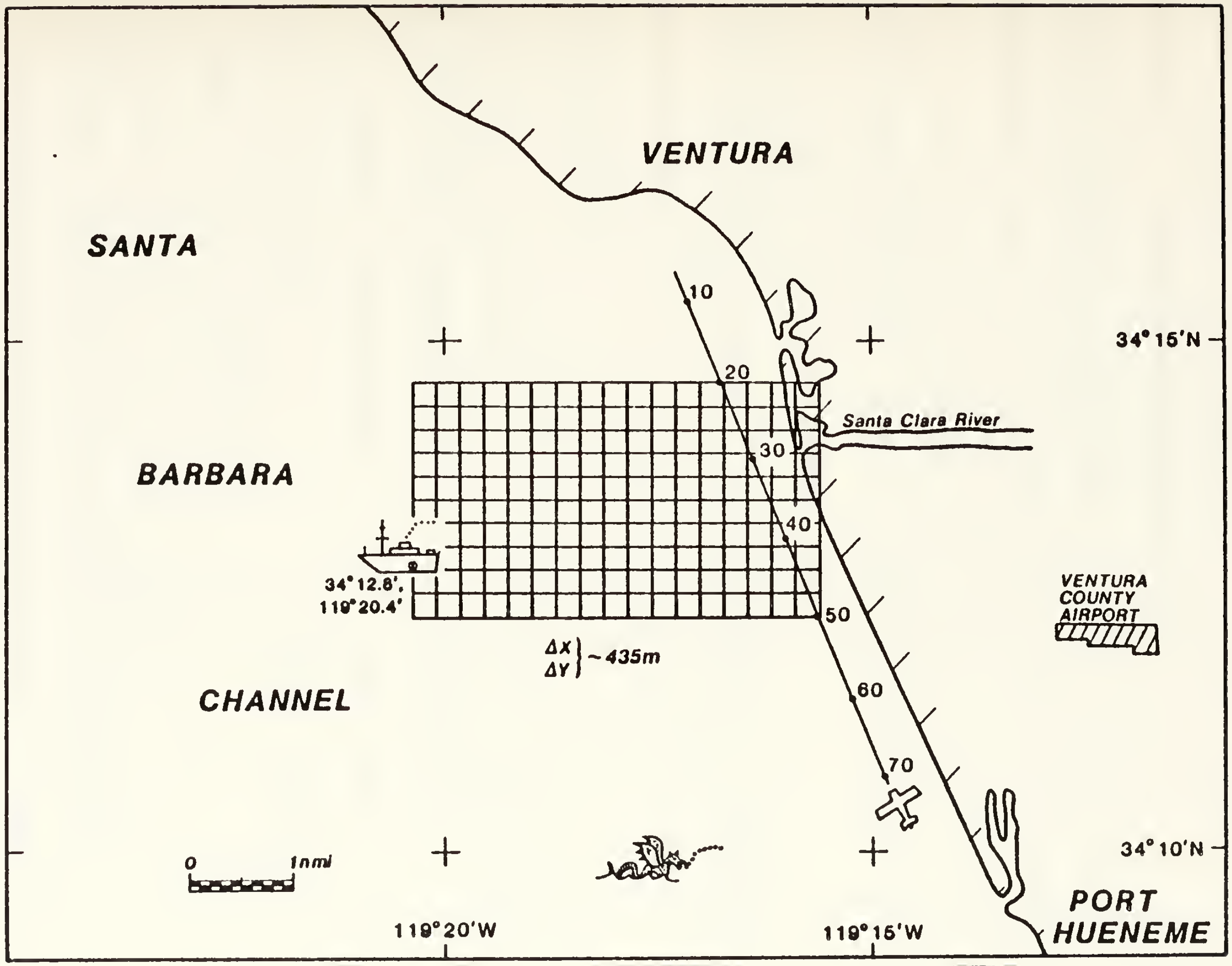


Figure 2. Experimental Area showing Locations of R/V Acania, Aircraft Track and Numerical Grid.

The aircraft flew through the plume at various elevations offshore and overland. The plume transect tracks pertinent to this study were made parallel to the coast approximately one-half mile offshore. The airborne sampling consisted of instaneous concentrations (PPT) at selected points at different levels over a period of six hours. The observations, recorded at locations 10-70 at altitudes of 61 and 91 m above MSL on January 29, 1980 are shown in Fig. 3. Average concentrations over the noted time period are shown at the bottom of each altitude block.

The following marine meteorological parameters were measured onboard the R/V Acania while anchored approximately 7.4 km offshore:

- relative wind speed
- wind speed fluctuation
- sea surface temperature
- sky cloud cover
- relative wind direction
- inversion height (acoustic sounder)
- vertical temperature and humidity profilies (shipboard radiosonde launch every 12 hours).
- air temperature
- dew point
- ship roll
- ship location

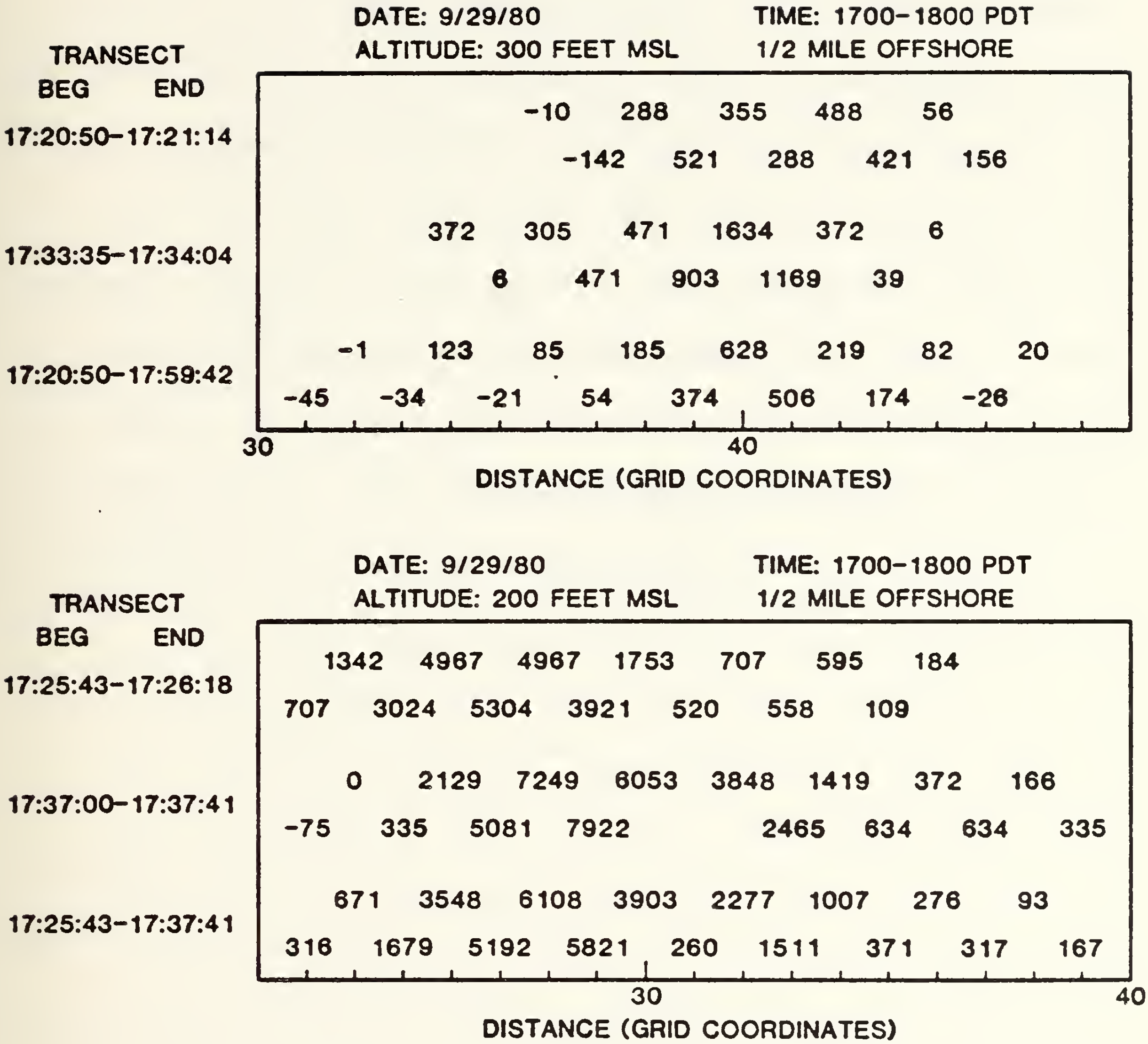


Figure 3. Aircraft observed Plume Concentrations (PPT) at Grid Coordinates at 61 and 91 m above MSL, 29 September 1980.

The tracer gas was released at a fixed rate through the exhaust of one of the ships motor generator sets. The generator was run at a constant speed resulting in a constant stack temperature and flow rate.

The above collected meteorological information enabled the data grid to be established and the atmospheric wind field, turbulence intensity, stability and buoyancy flux to be derived for inputs into the puff model. The puff model prediction based on this actual data formed the basis for the model performance evaluations carried out here. From this basis, different input variables were adjusted to note the effect on the advected concentrations--both in relation to each other and to the airborne measurements.

IV. MODEL BEHAVIOR

The Puff Model was run on the NPS IBM S/370 Model 3033 AP computer with two goals in mind; (1) familiarization with model performance under actual conditions and (2) a comparison of model predictions with observed data. The two goals are interrelated in the sense that atmospheric data collected in the aforementioned tracer study were used to form an initial prediction of the plume dispersion, and variations of that data were used to evaluate the limits of the model. The data used as input to the model represented the marine atmospheric conditions as determined from R/V Acania meteorological data at the time of the experiment.

Proper grid spacing was arrived at by considering puff spread, mean wind direction and the geographical area of interest. With the initial prediction in hand, data input variables of the model were adjusted and their effects (changes in prediction) noted. All model predictions were compared with the aircraft observed data.

A 7.4 X 4.3 km downwind area of interest was initially gridded into an 17 X 10 array. Distances between horizonal and vertical grid points were approximately 435 m (Fig. 2).

Since many of the aircraft observation times centered around 1730 hours (all times are Pacific Daylight Time), model puff releases were initiated at 1630. The 30-minute wind speed averages obtained from data taken onboard the ship between 1630 and 1730 were 4.7 and 4.8 ms^{-1}. The first advected puffs would be expected to arrive at the back edge of the grid slightly before 1700, and by 1730 a steady consistent plume would be passing through the area of the aircraft track. (The model showed, in fact, puffs leaving the back edge of the grid slightly before 30 minutes after puff release).

The average wind direction was recorded on the ship every 15 seconds. The standard deviations of the wind direction (sigma) were computed as approximate one minute averages. These, in turn, were averaged over 30 minutes to correspond with the 30-minute wind speed averages. The sigma values during the time of interest were 1.0 and 0.9 resulting in the very small turbulence intensity values of .0003 and .0002.

A delta Z value of 33 m was used to observe plume concentrations at the altitudes of 0, 33, 66 and 99 m above the surface. These levels were chosed for comparison with the aircraft transect altitudes of 61 and 91 m.

Fine scale vertical temperature and humidity plots were drawn based upon radiosonde soundings taken onboard the ship. The sounding taken at 1735 PDT (Figure 4) shows a shallow unstable layer near the surface topped by an inversion extending to near 400 m. A 80 m depth of the mixing layer was subjectively established. The potential temperature gradient computed by the formula

$$\frac{\partial \theta}{\partial z} = \frac{\partial T}{\partial z} + .0098\ z \qquad (1)$$

was found to be 1.0 deg K/100 m.

Basic data to determine source strength and heat emission from the ships stack were taken from Schacher, et al (1981). As previously mentioned, SF_6 gas was released through the ships motor generator exhaust at a constant rate. The stack temperature was 250 deg F, the flow rate was 7.13 * 10^3 $m^3 s^{-1}$. The SF_6 release rate was 47.91 lb hr^{-1}. The top of the ships stack--considered to be the source elevation-- was 4 m. The source strength was converted to 6.04 gm s^{-1} for input into the model.

Heat emission (H) in KW was determined by the formula

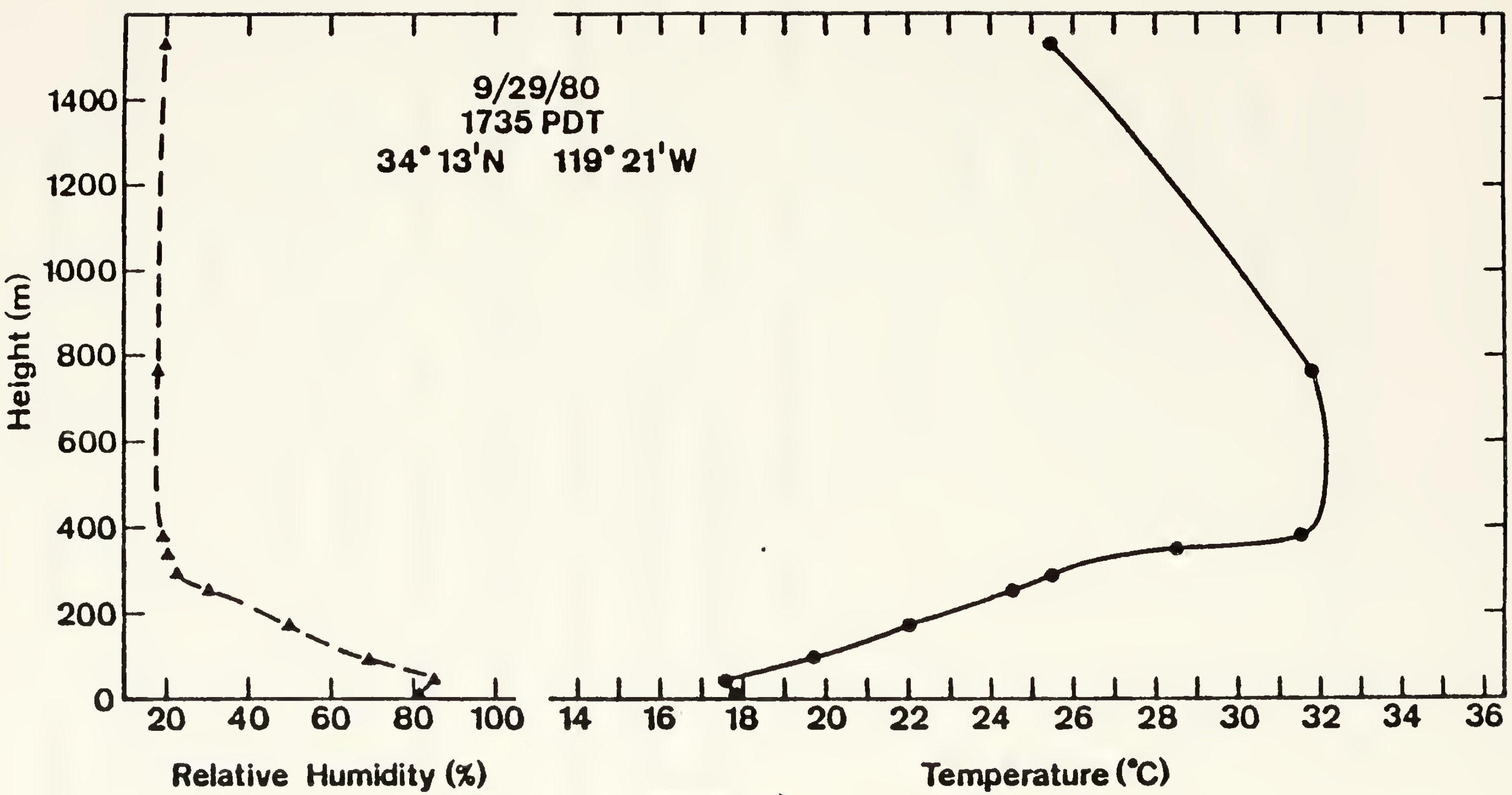


Figure 4. Radiosonde sounding taken onboard R/V Acania, 1745 PDT, September 29, 1981.

$$H = \Delta T * \frac{P}{RT} * C_p * \text{Flow} \tag{2}$$

where

delta T = temperature (stack - air) deg K

R = dry air gas constant

= $2.87 * 10^6$ erg/g deg K

P = 10^3 * P(mb) = dyne/cm^2

Cp = specific heat of dry air

= .24 cal/g deg K

Flow = 16.39 * 7.13 * 10^3 cm^3/s

The heat emission was thus computed as 15.07 KW.

Initially the model grid was established after noting the area of maximum airborne sampled concentrations (between points 24 and 43 of Fig. 3) and the location of the ship. It became obvious during early model runs that, with the actual wind direction input, the model predicted plume was being advected south of the grid towards point 60 on the aircraft track. Obviously, the steering wind, as measured onboard ship, was not constant all the way to the shore. A northward turning of the plume was indeed detected several times during the experiments by the aircraft. To compensate

for this effect, the source of the plume release was moved in the model three grid spaces (1305 m) to the north so that the maximum predicted plume concentrations would pass through the areas of the maximum airborne measured concentrations. No corrections were made to the model predicted plume concentrations because of this adjustment. However, one could reason that the predicted concentration values would be higher in comparison with measured values since the coastal turbulence and wind shift--which would tend to diffuse the plume--were not considered.

Initial model runs with the small turbulence intensity classifications of .0003 and .0002 failed to show plume concentrations greater than $1 * 10^{-12}$ in the grid at any level other than at the source. Apparently, the grid spacing was too large and the narrow plume was advecting between the grid points. In an effort to locate the plume, a combination of model runs were performed varying the turbulence intensity and grid spacing as shown in Table I.

In this table, a mixing level cap of 80 m was in effect for the model predictions. No concentrations above that level were allowed in the computations. As previously mentioned, the model mixing level cap totally reflects all pollutants back downward.

TABLE I. A Comparison of Predicted Concentrations at the Surface, 40 and 80 m at the East Edge of the Grid with Turbulence Intensities between .01 and .05. Mixing Level Limit is 80 m. E = (*10). Numbers in Parenthesis are Grid Numbers along Y Axis from Table II.

Turbulence Intensity	Delta Y								
			(4)	(5)	(6)	(7)			
			.68E-10	.16E-4	.22E-4	.20E-9			Sfc
			.31E-10	.70E-5	.10E-4	.91E-10			40 m
.01	108.75		.47E-11	.11E-5	.15E-5	.14E-10			80 m
			(4)		(5)				
			.69E-10		.22E-4				
.01	217.5		.31E-10		.10E-4				
			.47E-11		.15E-5				
			(6)						
			.69E-10						
.01	435		.31E-10						
			.47E-11						
			(6)				(7)		
			.19E-5				.56E-8		
.02	435		.17E-5				.50E-8		
			.12E-5				.37E-8		
			(6)				(7)		
			.66E-5				.48E-6		
.03	435		.67E-5				.49E-6		
			.62E-5				.45E-6		
		(5)	(6)				(7)	(8)	
		.57E-8	.72E-5				.26E-5	.28E-9	
.05	435	.59E-8 ...	.74E-5				.27E-5 ...	.29E-9	
		.58E-8	.72E-5				.26E-5	.29E-9	

With a grid spacing of 435 m and a turbulence intensity of .05, a plume concentration covering four grid spaces at the east end of the grid was produced. Predicted plume concentrations slowly decreased as the turbulence intensity was reduced to .02 (atmospheric stability increased). At an intensity of .01, the concentration dropped by about five orders of magnitude. Normally, one would expect increased concentrations with increased atmospheric stability. Perhaps the result noted here is due to the plume shrinking away from a grid point (and becoming more concentrated between the recorded grids) with the increase in stability.

To increase the grid resolution, the grid spacing was reduced by half to 217.5 m and again to 108.75 m. With each reduction the grid was reduced by half in the "Y" direction and doubled in the "X" direction thus keeping distances between grid spaces equal in all directions. This of course greatly increases the computational requirements. If only plume predictions along the back edge are needed (as in Table I), the downwind grid distance may be held constant at 435 m while the horizonal crosswind resolution is increased. In this way many unnecessary computations are not made. However, the increased horizonal crosswind resolution is

computed over the entire downwind grid, which in this case, is not necessary. A more satisfying solution to this problem is to install the capability of using a variable resolution grid with the model so that downwind areas of particular interest can be covered with a dense grid while other areas of not so much interest can be sparsely grided.

In order for the advection of the plume to remain on the array when increasing the horizonal crosswind resolution and decreasing the area exposed on the grid, the plume source was adjusted along the western boundary of the grid. The relationship of the vertical grid points to changes of the source location is shown in Table II. The plume source for each grid resolution is noted with an arrowhead. Grid points that are aligned vertically in the table have identical locations and should have the same predicted plume concentrations. As mentioned earlier, an increase of grid resolution does not affect the predicted concentration. Notice that for the same grid points in Table I, the predicted concentrations with a turbulence intensity of .01 remain constant with changes in grid spacing--only the grid resolution was changed.

TABLE II

The Relationship of the Y Axis along the Western Grid Edge to changes of Grid Distance between 435 and 108.75 m.

DELTA Y (m)	Grid Points Along the Y Axis															
435	4		5				6				7			8		9
217.5	0	1	2		3		4		5		6		7	8	9	
108.75			0	1	2	3	4	5	6	7	8	9				

From Table I it is obvious that the 435 m grid spacing is too large and that the higher resolution does indeed "see" concentrations that would otherwise be missed.

The problem of a increasingly narrow distance covered on the grid as resolution is increased can sometimes be at least partly corrected by reversing the X and Y coordinates and adjusting or rotating the advecting wind direction. This can easily be done with the use of the "TURN" model input parameter. This procedure sometimes becomes necessary since one of the grid directions is limited by the width of the output printer paper to less than or equal 10 grid units.

The model input variables, meteorological and source values were adjusted to note their effect on plume concentrations. A deeper understanding of how the model works and how the atmosphere affects dispersion can also be gained by

such adjustments. A turbulence intensity class of .05 was used, except when studying intensity itself, because it had previously demonstrated a good downwind grid coverage of the plume.

In order to note the effect of the maximum mixing level on the plume concentrations, several model predictions were run, varying only the height to which the plume was allowed to rise. Exact grid point reproductions were not possible since the model only allows the height of the mixing level to be an integer multiple of delta Z. The vertical grid spacing is therefore not equal. However, the antipicated trend of increased concentrations as the mixing level is lowered is evident from Table III.

The reflection/absorption of the plume at the surface is controlled by the model variable "REFLEC". Tests of the extremes of total absorption (0.0) and total reflection (1.0) were performed. The results showed a 50 percent reduction in plume concentrations at the west end of the grid with total absorption compared to total reflection in otherwise identical model runs.

The model has a self-imposed limitation of 100 puffs from all sources on the grid. The model will terminate if

TABLE III

Plume Concentrations between Surface and 99 m under Different Maximum Mixing Levels.

Max Mixing Level	(5)	(6)	(7)	(8)	
None	.44E-8	.55E-5	.20E-5	.22E-9	Sfc
	.43E-8	.54E-5	.19E-5	.21E-9	33 m
	.40E-8	.50E-5	.18E-5	.20E-9	66 m
	.36E-8	.45E-5	.16E-5	.18E-9	99 m
80 m	.57E-8	.72E-5	.26E-5	.28E-9	Sfc
	.59E-8	.74E-5	.27E-5	.29E-9	40 m
	.58E-8	.72E-5	.26E-5	.29E-9	80 m
	0	0	0	0	> 80 m
30 m	.64E-8	.81E-5	.29E-5	.32E-9	Sfc
	.65E-8	.81E-5	.29E-5	.32E-9	30 m
	0	0	0	0	> 30 m

this number is exceeded. A balance must be made between the rate at which puffs are released from the source (TAU) and the time it takes the puffs to be advected across the grid. A release rate of one puff every 40 seconds was predominantly used during this study.

The turbulence intensity variable was varied to include conditions that are more unstable. As atmospheric instability increases, the plume would be expected to expand whereas, with stable conditions, the plume should remain narrow and highly concentrated.

With the use of NPS contouring routines and the subroutine "DRAW", a visual comparison of the plume disposition and concentrations is available. Since the computed plume concentration varies over many orders of magnitude, the concentration values were converted to integer numbers by multiplying by $1. * 10^{13}$ and then taking the logarithm. These logarithms are then smoothed. Thus, a contour plot representing order of magnitude concentrations was be produced. As with the model variables "MAPTIM" and "KPLANS" which control the frequency and vertical levels of printer plots, "DRAW" can be called to contour concentrations at any time period and for any level required.

Plume concentration distributions for turbulence intensities of .05, .10 and .25, all other variables constant, are shown in Figs. 5, 6 and 7. As expected, the plume becomes wider and the concentration decreases as the turbulence intensity/diffusion increases and the atmosphere becomes less stable.

In Figs. 5-7, the plume source was located at grid point (0,6). The wide plume in the lower part of the plot is not real but is a function of the smoothing routine spreading the early puffs more than would be expected. Since the

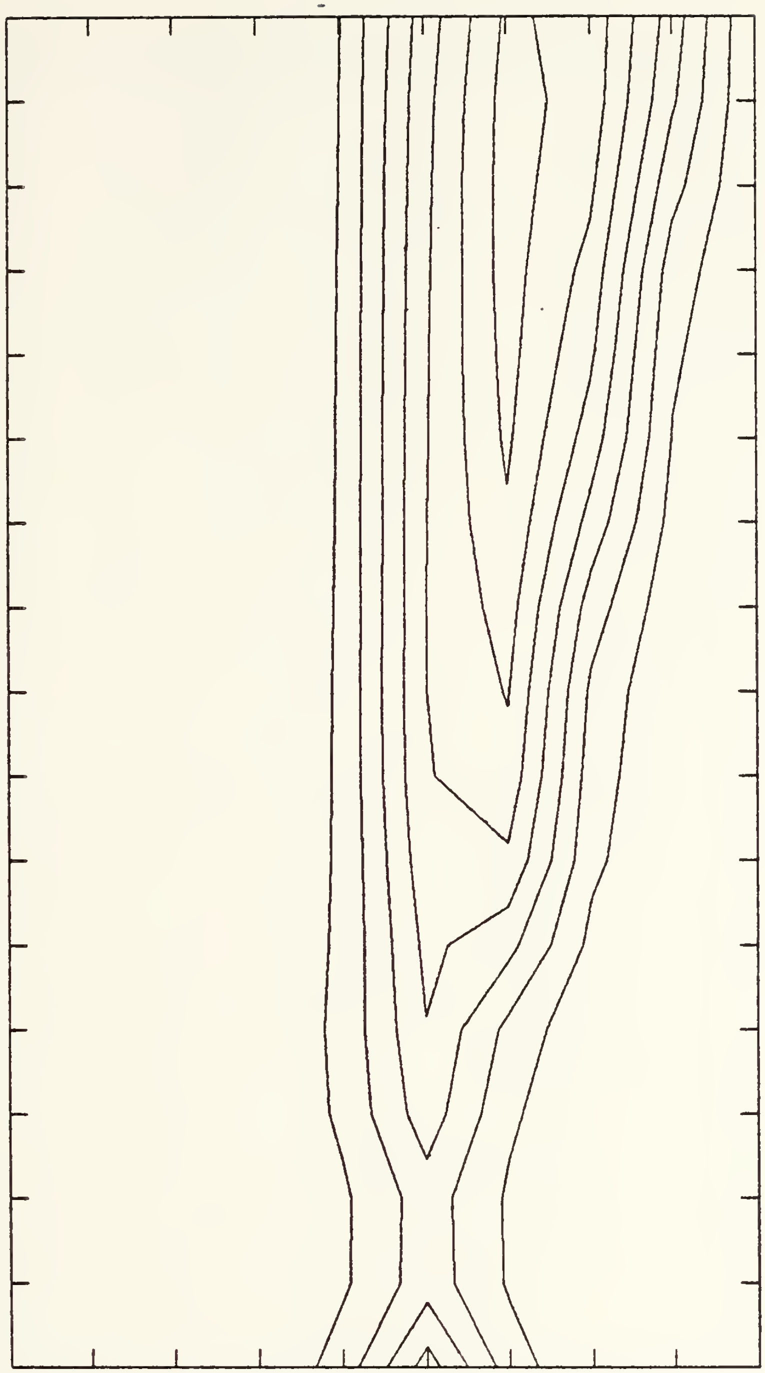


Figure 5. Orders of Magnitude of Plume Concentration with Turbulence Intensity equal to .05.

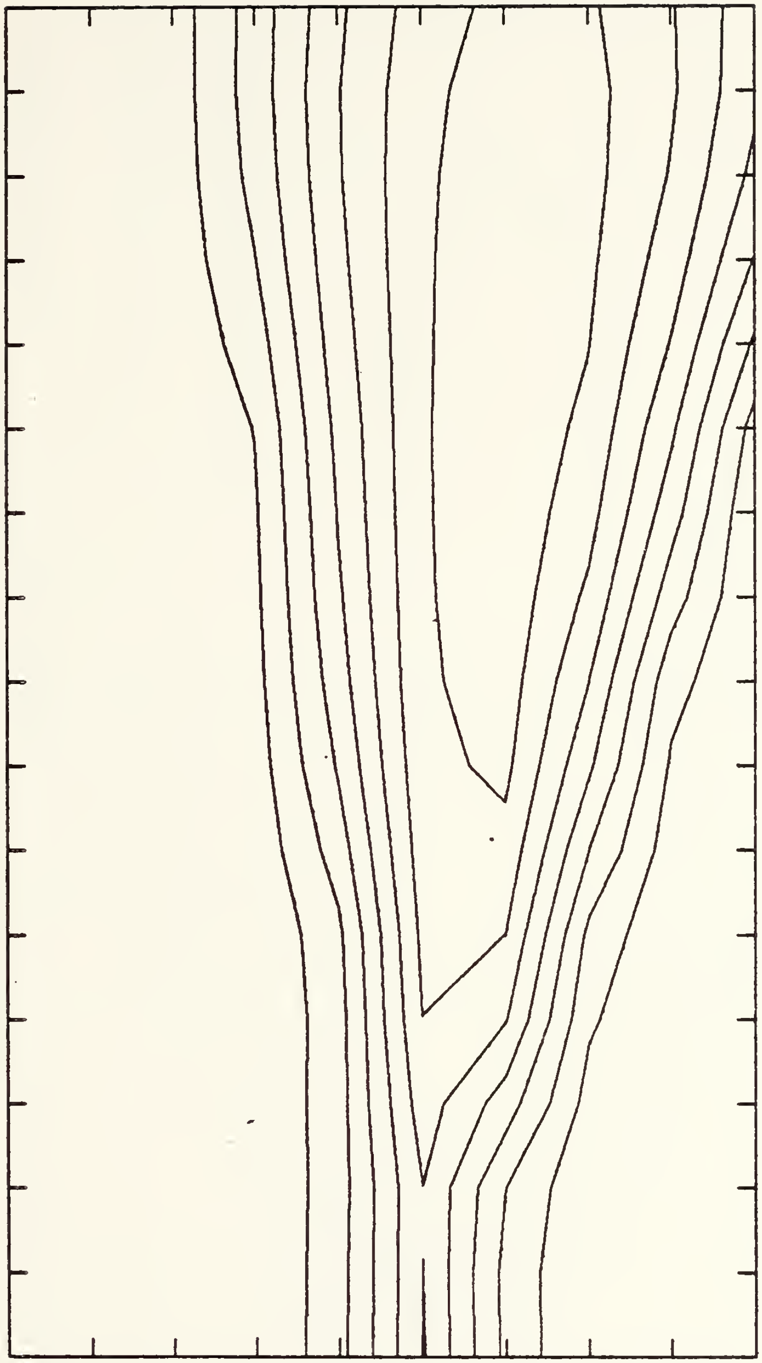


Figure 6. Same as Figure 5 except Turbulence Intensity equal to .10.

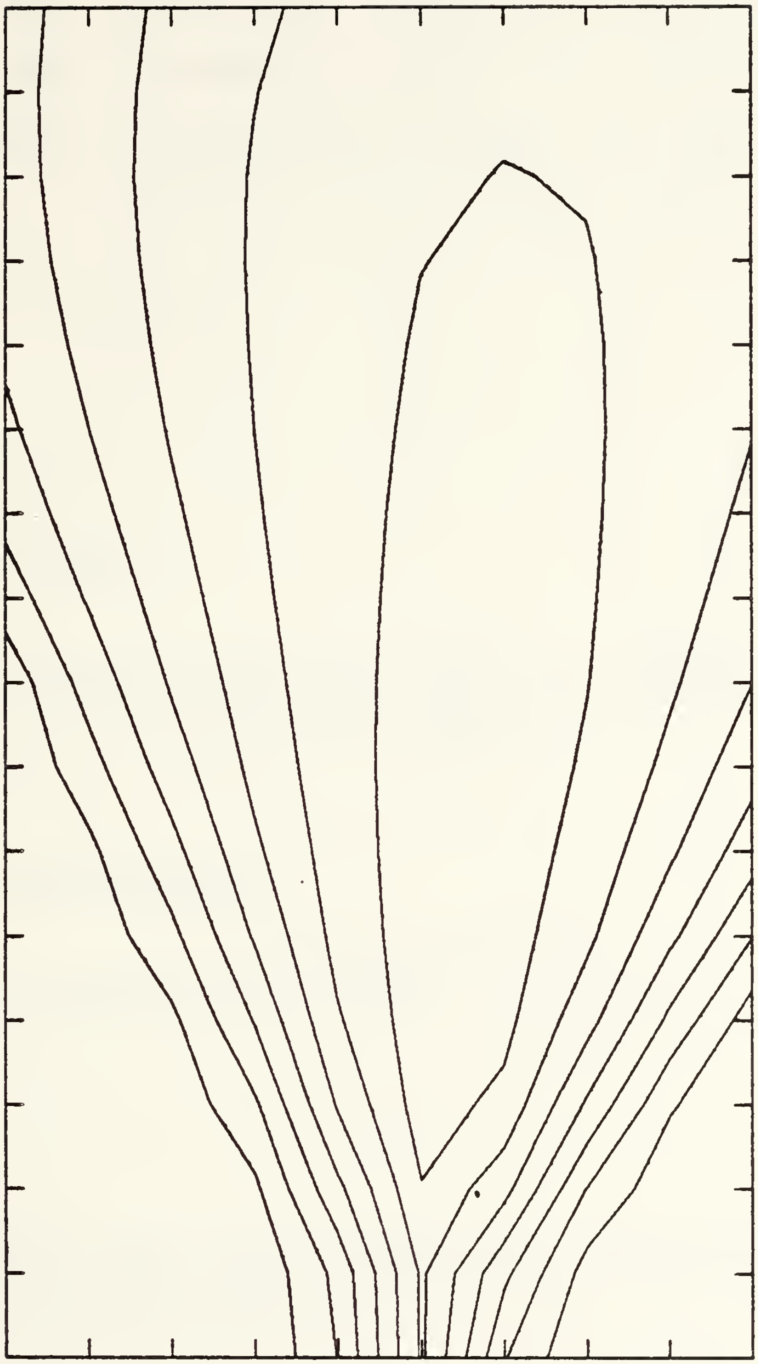


Figure 7. Same as Figure 5 except Turbulence Intensity equal to .25.

smoothing routine would tend to smooth strong concentrations near the source, the smoothing should be eliminated if the primary interest is near the source. Actually one would expect the puffs to behave as in Fig. 8, from Mikkelsen (1979), showing the relationship between the puff size and concentration, the rate of puff release (TAU) and the advecting wind speed U.

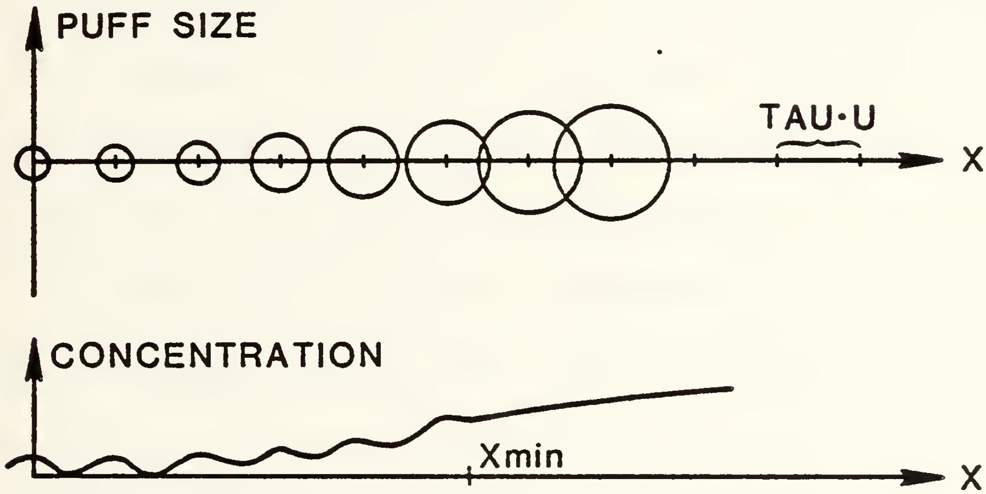


Figure 8. Relationship between Puff Size, Concentration, Puff Release Rate (TAU) and Advecting Wind Speed U (Mikkelsen, 1979).

puffs would have to travel the distance Xmin before they expand to a size where they effectively overlap and form a solid plume. From Figs. 5-7, one can see that plume concentrations have increased with distance and that a Xmin has been reached in the middle to upper part of the grid. It is at this point that the puff model would be expected to accurately predict plume concentrations. If the area of interest is before the present Xmin, the release rate of puffs would need to be increased so that the successive puffs would overlap sooner. Also noted that as the turbulence intensity increases, the area of maximum concentration of the plume expands while the central concentration decreases. This agrees with conservation of mass theorey.

To appreciate the relative importance of the source strength and buoyant heat flux, these variables (discussed in Chapter IV) were doubled separately and together and the concentrations compared to the concentrations from the actual conditions. Little or no changes in concentration were noted when the buoyant heat flux was doubled and source strength remained the same. However, when the source strength was doubled and heat flux held constant, the grid concentrations doubled as expected. Thus, under existing

conditions, the source strength was critical to the predicted plume concentrations while the buoyant heat flux, within the range tested, was not relevant. The vertical printer plots did show an initial puff rise soon after release due to the initial heat release but as the puff rose and expanded, it soon reached the ambient temperature and leveled off. The buoyant heat flux would probably be more important when dealing with a smaller scale grid or greater heat release.

V. DATA COMPARISON

No attempt was made to compare actual puff model concentration predictions at exact grid points to aircraft observations for the following reasons:

- The aircraft locations were approximations--the exact locations were not known. Large differences in predicted concentrations are seen with small grid separations as evidenced in Table II.

- As noted in Fig. 2, the aircraft observations were taken over a period of time at different levels--while the puff model produced multilevel instantaneous predictions.

- As mentioned earlier, the actual wind was not constant between the ship observation site and the oppsite side of the grid near shore. Since the model advects the puffs based upon ship observed wind, the behavior of actual plume would be different from predicted.

- Calabration procedures for the SF_6 continuous analyzer mounted onboard the aircraft were not available for instantaneous concentrations greater than 1010 PPT.

Therefore, a question of actual levels of SF_6 concentration in the higher ranges exists.

The puff model predicted concentrations are expressed in g/m^3 while the aircraft observations are shown as the volume of SF_6 per unit volume of air in PPT. A conversion between the predicted and observed concentrations was obtained by computing the partial pressure and molecular weight of SF_6 at standard pressure and temperature. A conversion of

$g/m^3 = (.63*10^{-11})$ * observed concentration (PPT)

was thus found.

Generally, the aircraft sampled concentrations (Fig. 2) show values between 100 and 8000 PPT. Converting these observed concentrations to predicted concentration units gives values between $.63*10^{-9}$ and $.50*10^{-7}$ g/m^3. These observed concentrations are much smaller than the values shown in Table II. Perhaps this difference could be explained by the fact that the puff model advected the plume toward the coast in the same direction under the same very stable conditions as observed on the ship. Any consideration of increased turbulence and wind shifts near shore would be expected to reduce the actual plume concentrations toward the observed concentration levels.

Increasing the turbulence intensity to 0.25 and keeping all other variables constant, the concentration values would decrease to the order of magnitude of 10^{-6}--closer to the observed concentrations. (This would require the wind direction standard deviation to increase from 1 to 28). However the increased instability would cause the plume to spread over a much greater area (Fig. 7) than observed by the aircraft.

VI. CONCLUSIONS AND RECOMMENDATIONS

The puff model has been demonstrated to be a versatile working dispersion model. Different combinations of input variables showed the expected reasonable results. The differences between model predicted and aircraft observed plume concentrations do not seem to be the fault of the model but mainly that of the highly variable meteorological conditions found along a coast.

Probably the most obvious conclusion reached from this study is that predicting the behavior of a plume moving over a marine environment onto a coastal region has significant problems. In all probability, atmospheric boundary layer conditions 7.4 km offshore can be very different from those observed in the more turbulent coastal region. The single point meteorological measurement at the source should not be expected to adequately represent plume characteristics as it nears a meteorologically variable coastline. Additional observations (primarily wind speed and direction), or other means of predicting the coastal meteorological conditions, would have to be incorporated into the puff model to adequately handle this problem.

The advantage of incorporating variable grid spacing within the puff model and the obvious benifits have already been discussed.

Presently, the mixing cap of the puff model is required to be located at an integer multiple of delta Z. More flexiability in this parameter to include any level, regardless of delta Z, would be benifical.

Along with the puff locations shown on the lineprinter output, a maximum concentration level of each puff would be helpful.

In future experiments, several aircraft tracks should be made further out from the coast in an attempt to avoid the turbulent coastal region. Observations thus obtained in a noncoastal environment would help to varify the model predictions without the coastal influence.

APPENDIX A

MAJOR SECTIONS OF THE PUFF MODEL

The Risø Puff Model has been described by (Mikkelsen, 1979). The code also is well documented with comment statements. With that information and the outline to be provided in this and the following appendices, the computational and input/output procedures will be obvious.

The program and input data are stored on cards for the sake of permanency. For efficient operational execution, the program and input data cards are read on a disk within the computer. The model can then be run at will without reference to the original data cards. Minor changes can easily be made directly on the disk both to the model and/or data before each execution.

The model can be separated into the following main sections:

A. Input Data

B. Initial

C. Calculating

D. Output

E. Error Diagnostics

F. Subroutines

These will be described separately in the following sections.

A. INPUT DATA SECTION

The input data includes the variables shown in Table IV.

TABLE IV

Input Data Variables for the Puff Dispersion Model.

Wind History	Potential Temperature Gradient
Turbulence Intensity	Buoyant Heat Flux
Grid Dimensions	Minimum Concentration of Interest
Mixing Depth	Reflection at Ground Level
Source Locations, Start/Stop Time, Strength, Heat Emission	
Number of Seconds between Advection Steps	
Number of Seconds between Printouts/Plots	
Number of Seconds between Puff Releases	

The wind field and stability class for the current time step are read at the start of the calculation section.

The variables listed above are printed as a input data check and a permanent record to accompany the actual output. In most cases the print command can be overridden by YES/NO options.

B. INITIAL SECTION

Based upon the input data from section (A), the initial section specifies and initializes parameters to be used in

the calculating section and is passed only once during execution of the model. The grid and some counters are initialized. Constants relating to reflectance, mixing depth and stability as well as those controlling the size of some of the loops within the model are established. Parameters such as number of puff releases per second, number of advection steps per second and number of advection steps per puff release are determined.

C. CALCULATION SECTION

Using current wind and stability class data read at the start of the calculation section, the model advects the puff centers and calculates the growth rate and plume rise of the puffs. It removes the puffs that have left the grid (horizonally and/or vertically). The predicted concentration is computed at the grid points to include pollutants from all nearby puffs.

D. OUTPUT SECTION

For time intervals designated by the input data, printer plots of the X-Y and Y-Z grid are produced. A maximum mixing level is marked on the Y-Z grid if in effect.

These plots include the source location and a trace of the plume from the release time to the maptime. Also printed at this interval is a X-Y table of grid concentrations for each vertical level of interest. These concentrations can be either accumulated or actual concentrations at the plot time.

Added to the puff model is a versatic plotter routine to smooth and contour the grid magnitude concentrations of the above tables.

E. ERROR DIAGNOSTIC SECTION

If the model is directed by the input data beyond the limits of the design of the program, the program is terminated by way of the error diagnostic section. It prints comments relating to commonly made input errors enabling the user to isolate problems.

F. SUBROUTINES

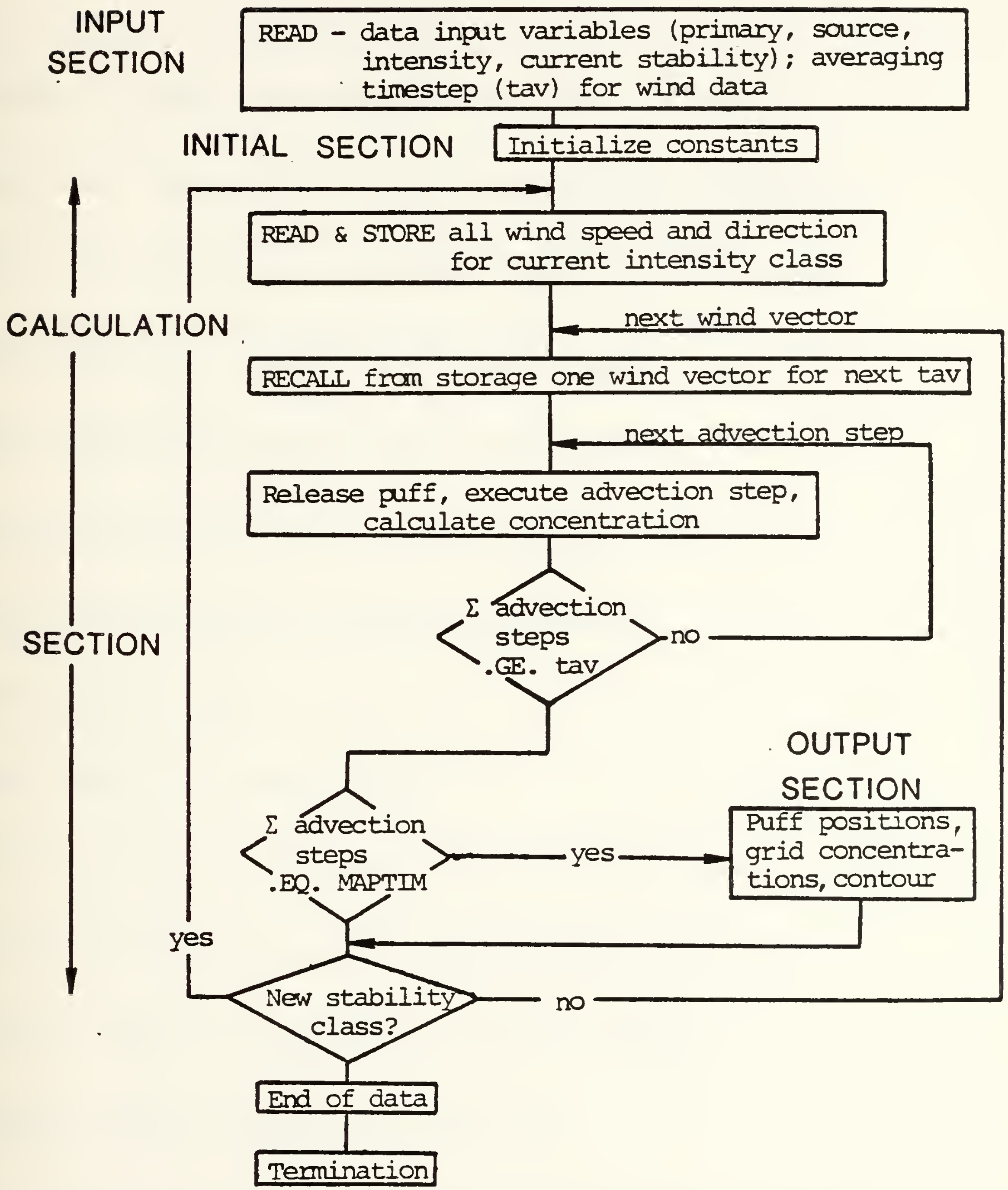
The subroutine "Sigris" calculates the puff size in the horizonal and vertical directions. It also estimates plume rise associated with pollutent buoyancy.

The subroutines "Ispace" and "Rspace" are used in the framework of the printer plots.

The subroutine "Draw" converts the plume concentrations to a logarithmic values, smoothes and then contours them using NPS inhouse contour subroutines. The values are converted to their logarithm values so that the problem of contouring over many orders of magnitude is simplified.

APPENDIX B

PUFF MODEL FLOW CHART



APPENDIX C

PUFF MODEL CONTRACTIONS

CHEMIN--Minimum grid concentration of interest

DELX,DELY,DELZ--Distance in meters between grid points

DOSE--Allows the concentration matrix to accumulate

DTDZ--Potential temperature gradient (K/M) (.GE. 0)

HEAT--Individual source heat emission (KW)

ICOLS--Number of columns in grid (.LE. 10)

INST--Instantaneous concentration matrix

ITIME--Start time

JROWS--Number of rows in grid

KPLANS--Number of vertical levels in grid (includes surface)

MAPTIM--Number of seconds between printer plots

NRELSE--Number of seconds to stop of release

NRMULT--Number of sources (.LE. 25)

NTADV--Integer number of seconds between advection steps

REFLEC--Reflection at ground level (0. none;1.0 total)

SOURNR--Number to identify source

SOURST--Strength for individual source (gm/s)

STOPRL--Individual source stop time (s)

STRTRL--Individual source start time (s)

TAU--Integer number of seconds between puff releases

TURN--Angle of rotation of wind direction

XSOURCE--X coordinate of source in grid units

YSOURCE--Y coordinate of source in grid units

ZM--Limited mixing depth (m)

APPENDIX D

LISTING OF PUFF MODEL COMPUTER CODE

```
// EXEC PGM=IEBGENER
//SYSPRINT DD DUMMY
//SYSIN DD DUMMY
//SYSUT2 DD UNIT=SYSDA,DISP=(NEW,PASS),
//   DCB=(RECFM=FB,LRECL=80,BLKSIZE=6400),
//   SPACE=(TRK,(1,1)),DSN=&FT02
//SYSUT1 DD *
WIND DATA SEPT 29 81
810929 1630 #1800#
/D
" 085*04.7" 085*04.8
/,
//   EXEC FRTXCLGN,NAME=CONRECQC
//FORT.SYSPRINT DD DUMMY
//FORT.SYSIN DD *
CFILE  1(KIND=DISK,TITLE='PRIMDA',FILETYPE = 7)                        PUF00010
CFILE  2(KIND=DISK,TITLE='VINDDA',FILETYPE=7)                          PUF00020
CFILE  3(KIND=DISK,TITLE='STABDA',FILETYPE=7)                          PUF00030
CFILE  4(KIND=DISK,TITLE='SOURCEDA',FILETYPE=7)                        PUF00040
CFILE  5(KIND=DISK,TITLE='INTSDA',FILETYPE=7)                          PUF00050
CFILE  PRINT(KIND=PRINTER,FILETYPE=7)                                  PUF00060
CFILE  6(KIND=PRINTER,FILETYPE=7)                                      PUF00070
C                                                                      PUF00160
C                                                                      PUF00170
C                                                                      PUF00180
C     THIS  MICRODIFFUSION  PROGRAM  REPRESENTS  THE STATE-OF-         PU00190
C     THE-ART CONCERNING THE DEVELOPMENT OF A NUMERIC DIFFUSION        PU00200
C     MODEL FOR OBSCURATION SMOKE.  ( RISO, MET. SEC. SEPT 1978)        UF00210
C                                                                      PUF00220
C     THE PROGRAM IS DOCUMENTED BY HEAVY USE OF COMMENT  STATEMENTS.   PUF00230
C                                                                      PUF00240
C     FOR COLLECTING AN OVERALL VIEW OF THE PROGRAM STRUCTURE, AS      PUF00250
C     WELL AS TO SET UP INPUT DATA FILES, IT IS ADVISED TO
C     CONSULT THE FLOWCHARTS AND DESCRIPTIONS IN THE CONSECUTIVE
C     REPORT.                                                          PUF00280
C                                                                      PUF00310
C                                                                      PUF00320
C                                                                      PUF00340
      COMMON HEATFX(25),I2,DMS,POINT,INTENS(14),STABPA,FBUFLX          PUF00350
     1,SPEED, CONST1,DELZ                                              PUF00360
      INTEGER TAU,POINT,ANGLE,XSB,XLB,YSB,YLB,ZSB,ZLB,YINT,XINTPF,YLINE PUF00370
     1,ZMG,ZINTPF,WINDAV,TOTTIM,SUMPUF,SOURNR,TPUFFS(25),XINT(100)     PUF00380
      INTEGER XSOURC(25),YSOURC(25), STRTRL(25),STOPRL(25)              UF00390

      LOGICAL LINE,COINCD,NOMXDP,GRRFLX                                PUF00410
      DIMENSION STRING(105),HORFRM(105),VERFRM(105),HRFRMZ(105),VRFRMZ(1PUF00420
     105),VERPLS(105),VRPLSZ(105),PARENT(105),NBUF(7),SBUF(7)          PUF00430
      REAL BL/' '/,SN1/'*'/,SN2/'I'/,SN3/'+'/,SN4/'-'/,SN5/'|'/,SN6/')'/PUF00440
```

```
      DIMENSION TITLE(18),WINDTX(18),PUFFTX(18),INTSTX(18),STABTX(18)    PUF00450
      DIMENSION PTABEL(25,100,7),SHIFT(100,7),CHI(50,50,10)               PUF00460

      DIMENSION ABC(10),SOURST(25),CPLOT(10,17),SOHT(25)                  PUF00480

      REAL DATA(14),TYPE(14),INTENS                                       PUF00500
                                                                           UF00510
      DATA NO/'NO'/,BLANK/' '/,A/'A'/,B/'B'/,C/'C'/,D/'D'/,E/'E'/
      DATA PUNK/'.'/,ASTER/'*'/,ANFO/'"'/,SLASH/'/'/,DOSE/'DOSE'/         PUF00540
      DATA AA/'#'/                                                        PUF00550
C                                                                         PUF00560
C                                                                         PUF00570
C*************************************************************************PUF00580
C*****INPUT DATA SECTION**************************************************PUF00590
C*************************************************************************PUF00600
C                                                                         PUF00610
C                                                                         PUF00630
C     INPUT DATA FROM DATA FILE PRIMDATA:                                 PUF00640
C     PRIMARY DATA FOR PUFF MODEL                                         PUF00650
C                                                                         PUF00660
C     READ PRIMDA,CARD NO. 1:                                             PUF00670
      READ(1,10)  ITIME,NRELSE,NSTEPS,ICOLS,JROWS,KP_ANS,NTADV            PUF00680
C     READ PRIMDA,CARD NO. 2:                                             PUF00690
      READ(1,20) MAPTIM,TAU,TURN                                          PUF00700
C     READ PRIMDA,TITLE STRING:                                           PUF00710
      READ(1,30) TITLE                                                    PUF00720
C     READ PRIMDA,CARD NO. 4 - 5 :                                        PUF00730
      READ(1,40) DELX,DELY,DELZ,CHEMIN,REFLEC                             PUF00740
C     READ PRIMDA,CARD NO. 5-9:                                           PUF00750
      READ(1,50) ABC(5),ABC(6),ABC(7),ABC(8),ABC(9)                       PUF00760
C     END OF PRIMDA - INPUT FILE.                                         PUF00770
C                                                                         PUF00780

    1 FORMAT(2H0 )                                                        PUF00810
    2 FORMAT(2H1 )                                                        PUF00820
   10 FORMAT(7I5)                                                         PUF00830
   20 FORMAT(5I5)                                                         PUF00840
   30 FORMAT(18A4)                                                        PUF00850
   35 FORMAT(1H ,18A4)                                                    PUF00860
   40 FORMAT(3F10.2,E10.4,F10.5)                                          PUF00870
   50 FORMAT(A2/A2/A2/A2/A4)                                              PUF00880
  100 FORMAT(6X,31HKEY PARAMETERS FOR CURRENT RUN:)                       PUF00890
  200 FORMAT(6X,13HITIME  =     ,I5,6X,13HNRELSE =     ,I5,6X,13HNSTEPS PUF00900
     1=     ,I5)                                                          PUF00910
  300 FORMAT(6X,13HICOLS  =     ,I5,6X,13HJROWS  =     ,I5,6X,13HKPLANS PUF00920
     1=     ,I5)                                                          PUF00930
  400 FORMAT(6X,13HNTADV  =     ,I5,6X,13HMAPTIM =     ,I5,6X,13HTAU    PUF00940
     1=     ,I5)                                                          PUF00950
```

```
  600 FORMAT(6X,8HDELX    =,F10.2,6X,8HDELY    =,F10.2,6X,8HDELZ    =,F10.2
     1)
  700 FORMAT(6X,8HCHEMIN =,E10.4,6X,8HREFLEC =,F10.5,6X,13HTURN     =
     1    ,I5)
C     SKIPPING LINE PRINTING OF PRIMDATA IF SPECIFIED
      IF(ABC(5) .EQ.  NO ) GO TO 751
      DO  750 I = 1,5
  750 WRITE(6,1)
      WRITE(6,35) TITLE
      WRITE(6,1)
      WRITE(6,1)
      WRITE(6,100)
      WRITE(6,1)
      WRITE(6,200) ITIME,NRELSE,NSTEPS
      WRITE(6,1)
      WRITE(6,300) ICOLS,JROWS,KPLANS
      WRITE(6,1)
      WRITE(6,400) NTADV,MAPTIM,TAU
      WRITE(6,1)
      WRITE(6,600) DELX,DELY,DELZ
      WRITE(6,1)
      WRITE(6,700) CHEMIN,REFLEC,TURN
      WRITE(6,1)
C
  751 CONTINUE
C
C     READ SOURCEDATA INPUT FILE
C
  800 FORMAT(A1,I2,A1)
  810 FORMAT(5I5,3F10.5)
  820 FORMAT(48H CURRENT SOURCEDATA : NUMBER OF ACTIVE SOURCES :,I4)
C
C     READ PUFFDATA,TITLESTRING
      READ(4,30) PUFFTX
      WRITE(6,30) PUFFTX
C     READ NUMBER OF MULTISOURCES:NRMULT
      READ(4,800) ABC(3),NRMULT,ABC(4)
      WRITE(6,800) ABC(3),NRMULT,ABC(4)
C     INPUT FORMAT TESTING:
      IF(ABC(3).NE.AA.OR.ABC(4).NE.AA) GO TO 8920
C     READ INDIVIDUAL SOURCEDATA:
C
C     SETTING FRAMEDATA: (M) SMALL-X, (M) FULL-X, ETC.
      MFX = ICOLS
      MSX = 1
      MFY = JROWS
      MSY = 1
      MFZ = KPLANS
```

```
      MSZ = 1                                                            PUF01430
      XSB=MSX-1                                                          PUF01440
      XLB=MFX-1                                                          PUF01450
      YSB=MSY-1                                                          PUF01460
C     BOTTOM OF FRAME : YBB = YSB - .9                                   PUF01470
      YBB = YSB - .9                                                     PUF01480
      ZSB = MSZ - 1                                                      PUF01490
      ZLB = MFZ - 1                                                      PUF01500
      YLB=MFY-1                                                          PUF01510
      YLL=YLB + 0.1                                                      PUF01520
      DO 850 I = 1,NRMULT                                                PUF01530
      READ(4,810)  SOURNR,XSOURC(I),YSOURC(I),STRTRL(I),                 PUF01540
     2STOPRL(I),SOURST(I),HEATFX(I),SOHT(I)                              PUF01550
      WRITE(6,810) SOURNR,XSOURC(I),YSOURC(I),STRTRL(I),
     2STOPRL(I),SOURST(I),HEATFX(I),SOHT(I)
C     TESTING INDIVIDUAL SOURCEDATA:                                     PUF01560
      IF(I.NE.SOURNR) GO TO 8910                                         PUF01570
C     OFF GRID TEST FOR SOURCE COORDINATES:                              PUF01580
      IF(XSOURC(I).GT.XLB.OR.XSOURC(I).LT.XSB.OR.YSOJRC(I).GT.YLB.OR.YSOPUF01590
     1URC(I).LT.YSB) GO TO 9000                                          PUF01600
  850 CONTINUE                                                           PUF01620
C                                                                        PUF01630
      WRITE(6,2)                                                         PUF01640
      WRITE(6,1)                                                         PUF01650
      WRITE(6,35) PUFFTX                                                 PUF01660
      WRITE(6,1)                                                         PUF01670
      WRITE(6,820) NRMULT                                                PUF01680
      WRITE(6,1)                                                         PUF01690
C                                                                        PUF01700
C     SETTING UP STRING VARIABLES FOR PLOTTING PURPOSES                  PUF01710
      DO 911 N = 1,105                                                   PUF01720
      STRING(N)=BL                                                       PUF01730
      VERFRM(N)=BL                                                       PUF01740
      VERPLS(N) = BL                                                     PUF01750
  911 HORFRM(N) = BL                                                     PUF01760
      NY1=MFX*10                                                         PUF01770
      DO 916 I = MSX,NY1                                                 PUF01780
      NY2=I+4                                                            PUF01790
      DO 915 NN = I,NY2                                                  PUF01800
  915 HORFRM(NN)= SN4                                                    PUF01810
      HORFRM(I+5) = SN2                                                  PUF01820
      NY3=I+6                                                            PUF01830
      NY4=I+9                                                            PUF01840
      DO 916 NN = NY3,NY4                                                PUF01850
  916 HORFRM(NN)= SN4                                                    PUF01860
      VERFRM(10*MFX  + 3) = SN5                                          PUF01870
      VERPLS(10*MFX  + 3) = SN3                                          PUF01880
C                                                                        PUF01890
```

```
C     OUTPRINTING CURRENT SOURCE POSITION(S) IN GRID PICTURE                PUF01920
C                                                                           PUF01930
C     SKIP PLOT OF SOURCE POSITIONS IF SPECIFIED IN ᵓRIMDA                  PUF01940
      IF(ABC(6) .EQ.  NO ) GO TO 999                                        PUF01950
C                                                                           PUF01970
      IF(ICOLS.GT. 10) GO TO 995                                            PUF01980
  860 FORMAT(1H ,49X,33H CURRENT SOURCE DATA AS SPECIFIED,/50X,27H IN SOPUF01990
     1URCE DATA INPUT FILE:,/)                                              PUF02000
  865 FORMAT(1H0,50X,'SOURCES ARE REPRESENTED BY:',/55X,'SOURCE NUMBER', UF02010
     1/55X,'START TIME (SEC)',/55X,'STOP TIME (SEC)',/55X,
     2,'SOURCE STRENGTH',/55X,'BUOYANT HEAT FLUX.'//)

  870 FORMAT(2H0 ,16H Y COORDINATE OF,25X,32H X COORDINATE OF THE GRID PPUF02050
     1OINTS/2X,16H THE GRID POINTS,I8,9I10/)                                PUF02060
  871 FORMAT(2H0 ,16H Y COORDINATE OF,25X,32H Z COORDINATE OF THE GRID PPUF02070
     1OINTS/2X,16H THE GRID POINTS,I8,9I10/)                                PUF02080
C                                                                           PUF02090
      WRITE(6,860)                                                          PUF02100
      WRITE(6,865)                                                          PUF02110
      WRITE(6,870)  (I,I=XSB,XLB)                                           PUF02120
C     WRITING DATA INTO GRIDPOINTS:                                         PUF02130
  910 FORMAT(1H+,I11,5X,2H +,105A1)                                         PUF02140
  912 FORMAT(1H+, 19X, 105A1)                                               PUF02150
  913 FORMAT(1H ,17X,1H|,105A1/1H ,17X,1H|,105A1)                           PUF02160
  914 FORMAT(1H+ ,17X,1H|,105A1)                                            PUF02170
C                                                                           PUF02190
C                                                                           PUF02200
      WRITE(6,1)                                                            PUF02210
      WRITE(6,912) HORFRM                                                   PUF02220
      WRITE(6,913) VERFRM,VERFRM                                            PUF02230
      MAX =JROWS -1                                                         PUF02240
      NY5=MAX+1                                                             PUF02250
      DO 950    NY6=1,NY5                                                   PUF02260
      I=NY6-1                                                               PUF02270
      MAXMI  = MAX - I                                                      PUF02280
      WRITE(6,910)  MAXMI, VERPLS                                           PUF02290
      DO 920 J=1,NRMULT                                                     PUF02300
      IF(MAX-I .NE. YSOURC(J) )  GO TO 920                                  PUF02310
      CALL ISPACE(XSOURC(J),J)                                              PUF02320
  920 CONTINUE                                                              PUF02330
      WRITE(6,913) VERFRM,VERFRM                                            PUF02340
C                                                                           PUF02350
      DO 932 J = 1,NRMULT                                                   PUF02360
      IF(MAX-I .NE.YSOURC(J)) GO TO 932                                     PUF02370
      WRITE(6,914) VERFRM                                                   PUF02380
      CALL ISPACE(XSOURC(J),STRTRL(J))                                      PUF02390
  932 CONTINUE                                                              PUF02400
      WRITE(6,913) VERFRM,VERFRM                                            PUF02410
```

```
C                                                                       PUF02420
      DO 934 J = 1,NRMULT                                               PUF02430
      IF(MAX-I .NE. YSOURC(J)) GO TO 934                                PUF02440
      WRITE(6,914) VERFRM                                               PUF02450
      CALL ISPACE(XSOURC(J),STOPRL(J))                                  PUF02460
  934 CONTINUE                                                          PUF02470
      WRITE(6,913) VERFRM,VERFRM                                        PUF02480
C                                                                       PUF02490
      DO 940 J=1,NRMULT                                                 PUF02500
      IF(MAX-I .NE. YSOURC(J) )  GO TO 940                              PUF02510
      WRITE(6,914) VERFRM                                               PUF02520
      CALL RSPACE(XSOURC(J),SOURST(J))                                  PUF02530
  940 CONTINUE                                                          PUF02540
      WRITE(6,913) VERFRM,VERFRM                                        PUF02550
C                                                                       PUF02560
      DO 930 J=1,NRMULT                                                 PUF02570
      IF(MAX-I .NE. YSOURC(J) )  GO TO 930                              PUF02580
      WRITE(6,914) VERFRM                                               PUF02590
      CALL RSPACE(XSOURC(J),HEATFX(J))                                  PUF02600
  930 CONTINUE                                                          PUF02610
      WRITE(6,913) VERFRM,VERFRM                                        PUF02620
      WRITE(6,913) VERFRM,VERFRM                                        PUF02630
C                                                                       PUF02640
  950 CONTINUE                                                          PUF02660
      WRITE(6,1)                                                        PUF02670
      WRITE(6,912) HORFRM                                               PUF02680
C                                                                       PUF02700
      GO TO 999                                                         PUF02710
  990 FORMAT(53H SOURCE DATA PLOT SUPPRESSED BECAUSE"ICOLS"EXCEEDS 10)  PUF02720
  995 WRITE(6,990)                                                      PUF02730
  999 CONTINUE                                                          PUF02740
C                                                                       PUF02750
C     DEFINE STABILITY AND INTENSITY CLASSES                            PUF02760
C     INPUT FROM INTENSITY - DATA: INTSDA                               PUF02770
C                                                                       PUF02780
  960 FORMAT(14 F5.4)                                                   PUF02790
  965 FORMAT(1H0, 46H IN THE CURRENT RUN, THE STABILITY-CLASSES ARE,/41HPUF02800
     1  CONNECTED TO INTENSITY DATA AS FOLLOWS:)                        PUF02810
  970 FORMAT(1H ,21H STABILITY CLASS NO.:,I3,13I5)                      PUF02820
  975 FORMAT(1H ,21H INTENSITY DATA      :, 14F5.4)                     PUF02830
C                                                                       PUF02840
C     READ INTSDA,TITLE-STRING:                                         PUF02850
      READ(5,30) INTSTX
C     WRITE(6,30) INSTX
C     READ INTSDA, NO. OF INTENSITY-CLASSES: NRINCL                     PUF02870
      READ(5,800) ABC(3),NRINCL,ABC(4)                                  PUF02880
C     WRITE(6,802) NRINCL
C     INPUT FORMAT TESTING:                                             PUF02890
```

```
  802 FORMAT(1X,I5)
      IF(ABC(3).NE.AA.OR.ABC(4).NE.AA) GO TO 8890                       PUF02900
C     READ INTENSITY-CLASSES INTO REAL ARRAY: INTENS                    PUF02910
      READ(5,960,END=801) (INTENS(I),I=1,NRINCL)                        PUF02920
C     WRITE(6,960) (INTENS(I),I=1,NRINCL)
C                                                                       PUF02930
C     OUTPRINTING CURRENT INTENSITY CLASSES:                            PUF02940
C                                                                       PUF02950
C     SKIP PRINTING OF INTENSITY DATA IF SPECIFIED IN PRIMDA
  801 IF(ABC(7).EQ. NO ) GO TO 980                                      PUF02970
      WRITE(6,2)                                                        PUF02980
      WRITE(6,35) INTSTX                                                PUF02990
      WRITE(6,1)                                                        PUF03000
      WRITE(6,965)                                                      PUF03010
      WRITE(6,970) (I,I=1,NRINCL)                                       PUF03020
      WRITE(6,975) (INTENS(I),I=1,NRINCL)                               PUF03030
      WRITE(6,1)                                                        PUF03040
      WRITE(6,1)                                                        PUF03050
  980 CONTINUE                                                          PUF03060
C                                                                       PUF03070
C     END OF INTENSITY DATA SECTION.                                    PUF03080
C                                                                       PUF03100
C     INPUT FROM STABILITY DATA:STABDA                                  PUF03110
C
C     READ STABDA,TITLESTRING:                                          PUF03120
      READ(3,30) STABTX
C     READ STABDA,POTENTIAL TEMPERATURE GRADIENT (>0).                  PUF03140
      READ(3,889) DTDZ                                                  PUF03150
C     READ STABDA,LIMIT OF MIXING DEPTH: ZM (METERS).                   PUF03160
      READ(3,992) ZM                                                    PUF03170
C     INDATA-TEST ON ZM:                                                PUF03180
      IF(AMOD(ZM,DELZ) .NE. 0.)GO TO 8880
C                                                                       PUF03200
C     OUTPRINTING CURRENT STABILITY-DATA:                               PUF03210
  889 FORMAT(F10.4)                                                     PUF03220
  991 FORMAT(1H0,45H IN THE CURRENT RUN,THE POTENTIAL TEMPERATURE/21H  GPUF03230
     1RADIENT IS SET TO:,F10.4)                                         PUF03240
  992 FORMAT(F10.2)                                                     PUF03250
  993 FORMAT(1H0,36H NO FINAL MIXING DEPTH IS SPECIFIED.)               PUF03260
  994 FORMAT(1H0,32H THE MIXING LAYER IS LIMITED AT:,F10.2,8H METERS.)  PUF03270
      WRITE(6,1)                                                        PUF03280
      WRITE(6,1)                                                        PUF03290
      WRITE(6,1)                                                        PUF03300
      WRITE(6,35) STABTX                                                PUF03310
      WRITE(6,1)                                                        PUF03320
      WRITE(6,1)                                                        PUF03330
      WRITE(6,991) DTDZ                                                 PUF03340
      WRITE(6,1)                                                        PUF03350
```

```
      WRITE(6,1)                                                        PUF03360
      IF(ZM .EQ. 0.) WRITE(6,993)                                       PUF03370
      IF(ZM .GT. 0.) WRITE(6,994) ZM                                    PUF03380
C                                                                       PUF03390
C     END OF STABILITY DATA SECTION.                                    PUF03400
C                                                                       PUF03410
C     INPUT FROM WINDDATA:                                              PUF03420
 1110 FORMAT(I6,1X,I4,1X,1A1,I4,1A1)                                    PUF03440
 1120 FORMAT(1H0,28HCURRENT WINDDATA: STARTDATE=,I6,4X,10HSTARTHOUR=,I4,PUF03450
     14X,14HWINDAV.(SEC.)=,I4)                                          PUF03460
C     READ WINDDA,TITLE STRING:                                         PUF03470
      READ(2,30) WINDTX
C     READ WINDDA,STARTTIME AND WINDFIELD AVERAGING TIME:               PUF03490
      READ(2,1110) DATE,STRTHR,ABC(1),WINDAV,ABC(2)                     PUF03500
C     INPUT FORMAT TESTING:                                             PUF03510
      IF(ABC(1).NE.AA.OR.ABC(2).NE.AA) GO TO 8990                       PUF03520
      WRITE(6,2)                                                        PUF03530
      WRITE(6,1)                                                        PUF03540
      WRITE(6,1)                                                        PUF03550
      WRITE(6,1)                                                        PUF03560
      WRITE(6,35) WINDTX                                                PUF03570
      WRITE(6,1)                                                        PUF03580
      WRITE(6,1120) DATE,STRTHR,WINDAV                                  PUF03590
C                                                                       PUF03600
C     TESTING ON SPECIFIED TIME INCREMENTS: TAU,NTADV,WINDAV:           PUF03610
      ITEST1 = MOD(TAU,NTADV)                                           PUF03620
      IF(ITEST1.NE.0) GO TO 8980                                        PUF03630
      ITEST2 = MOD(WINDAV,NTADV)                                        PUF03640
      IF(ITEST2.NE.0) GO TO 8970                                        PUF03650
C     END OF FIXED WINDDATA SPECIFICATIONS.                             PUF03660
C                                                                       PUF03670
C                                                                       PUF03680
C***********************************************                        PUF03700
C*****INITIAL SECTION***************************                        PUF03710
C***********************************************                        PUF03720
C                                                                       PUF03730
C     (THIS PART OF THE PROGRM IS ONLY PASSED ONCE.)                    PUF03740
C                                                                       PUF03750
 1130 FORMAT( 14(A1,A4))                                                PUF03760
C     COUNTER FOR STABILITY SPECIFICATIONS GIVEN BY WINDDATA: NRSTAB    PUF03770
      NRSTAB =0                                                         PUF03780
C     INITIATING A THREE DIMENSIONAL GRID: CHI
      DO 1200 I = 1,ICOLS                                               PUF03800
      DO 1200 J = 1,JROWS                                               PUF03810
      DO 1200 K = 1,KPLANS                                              PUF03820
 1200 CHI(I,J,K) = 0                                                    PUF03830
C                                                                       PUF03840
C                                                                       PUF03850
```

```
C      NUMBER OF PUFF RELEASES PER SEC: TAUINVERS.                        PUF03860
       TAUINV = 1.0/ FLOAT(TAU)                                           PUF03870
C                                                                         PUF03880
C      NUMBER OF ADVECTION STEPS PER SEC.: ADSTPS.                        PUF03890
C      ADSTPS = 1.0/ FLOAT(NTADV)                                         PUF03900
C      BASIC DOSE PER PUFF:(GRAM/SEC.)*TAU  =  GRAM/PJFF.                 PUF03910
       BADOPP = 1*TAU                                                     PUF03920
C                                                                         PUF03930
C      NUMBER OF BASIC ADVECTION STEPS (INTEGER NUMBER) PER PUFF RELEASE:PUF03940
       NADPRP = TAU/NTADV                                                 PUF03950
C                                                                         PUF03960
C      NUMBER OF BASIC ADVECTION STEPS (INTEGER NUMBER) PER WINDFIELDSP.  PUF03970
       NADPRW= WINDAV/NTADV                                               PUF03980
C                                                                         PUF03990
C                                                                         PUF04000
                                                                          PUF04010
C      TOTAL RUNTIME COUNTER: TOTTIM.                                     PUF04020
       TOTTIM =0                                                          PUF04030
C                                                                         PUF04040
C                                                                         PUF04050
C      COUNTER FOR REMOVED PUFFS: LEAVE                                   PUF04060
       LEAVE = 0                                                          PUF04070
C      STABILITY PARAMETER FOR PLUMERISE:                                 PUF04080
C      STABPA = G/T*(DTHETE/DZ)                                           PUF04090
       STABPA = .033*DTDZ                                                 PUF04100
C      CONSTANT IN CONNECTION WITH PLUMERISE FORMULA FOR USE IN           PUF04110
C      SUBROUTINE SIGRIS: CONST1.                                         PUF04120
       CONST1 = 0.6667 * 1.6**1.5                                         PUF04130
C                                                                         PUF04140
C      IF MIXING DEPTH IS NOT SPECIFIED,SET NOMXDP = .TRUE.
       IF(ZM .EQ. 0.) NOMXDP = .TRUE.                                     PUF04160
C                                                                         PUF04170
C      IF REFLECTANCE AT GROUND LEVEL IS SPECIFIED,SET GRRFLX = .TRUE.
       IF(REFLEC .GT. 0.) GRRFLX = .TRUE.                                 PUF04190
C      MIXING DEPTH IN GRID-UNITS: ZMG
       ZMG = ZM/DELZ                                                      PUF04210
C      TESTING THAT MIXING DEPTH IS INSIDE GRID:                           UF04220
       IF(ZMG .GT. (KPLANS -1)) GO TO 8870                                PUF04230
C                                                                         PUF04240
C      END OF INITIAL SECTION                                             PUF04250
C                                                                         PUF04260
C                                                                         PUF04270
C*****************************************************                    PUF04280
C*****CALCULATION SECTION************************                         PUF04290
C*****************************************************                    PUF04300
C                                                                         PUF04310
C      READING STABILITY CLASS AND WINDDATA FROM INPUTFILE:               PUF04320
 1135 READ (2,1130)  (  TYPE(I),DATA(I)  , I = 1,14)                      PUF04330
```

```
      BACKSPACE 2
      IF(TYPE(1).EQ.ANFO) READ(2,1131)(NBUF(I),SBUF(I),I=1,7)
      IF(TYPE(1).EQ.ANFO)WRITE(6,1131)(NBUF(I),SBUF(I),I=1,7)
      IF(TYPE(1).EQ.SLASH) READ(2,1130)
 1131 FORMAT(7(1X,I4,1X,F4.1))
C     LOOP THRU WINDDATA AT SPECIFIED TIMESTEPS                         PUF04350
      I = 1                                                             PUF04360
      IF(TYPE(1).NE.SLASH)GO TO 1150                                    PUF04370
      NRSTAB = NRSTAB + 1                                               PUF04380
C                                                                       PUF04390
C     COUNTING NUMBER OF WINDDATA SPECIFICATIONS: IWDASP                PUF04400
      IWDASP = 0                                                        PUF04410
C     READING STABILITY CATEGORY FROM WINDDATA:                         PUF04420
      CLASS =DATA(1)                                                    PUF04430
      IF(CLASS.EQ. A )  POINT =1                                        PUF04440
      IF(CLASS.EQ. B )  POINT =2                                        PUF04450
      IF(CLASS.EQ. C )  POINT =3                                        PUF04460
      IF(CLASS.EQ. D )  POINT =4                                        PUF04470
      IF(CLASS.EQ. E )  POINT =5                                        PUF04480
      IF(CLASS.EQ.PUNK)GO TO 8930                                       PUF04490
      IF(CLASS.EQ.BLANK) GO TO 8940                                     PUF04500
 1140 FORMAT(53H PROGRAM STOPPED ORDINARILY FM WINDDATA SPECIFICATION)
      WRITE(6,1)                                                        PUF04530
      WRITE(6,1141) NRSTAB,POINT                                        PUF04540
      WRITE(6,1)                                                        PUF04550
 1141 FORMAT(4H THE,I3,38H. STABILITY SPECIFICATION CLASS IS NO.,I1)    PUF04560
      GO TO 1135                                                        PUF04570
C                                                                       PUF04580
C     INPUT STRUCTURE TEST:                                             PUF04590
 1150 IF(TYPE(I).NE.ANFO .OR.TYPE(I+1).NE.ASTER) GO TO 1160             PUF04600
C                                                                       PUF04610
      IWDASP  = IWDASP + 1                                              PUF04620
C     CURRENT WINDDATA:                                                 PUF04630
      JI=(I+1)/2                                                        PUF04640
      ANGLE=NBUF(JI)                                                    PUF04650
      SPEED=SBUF(JI)                                                    PUF04660
      GO TO 1175                                                        PUF04670
 1160 IF(TYPE(I).NE.BLANK.OR.TYPE(I+1).NE.BLANK) GO TO 8950             PUF04680
C     READ NEW DATA IN LINE 1135                                        PUF04690
      GO TO 1135                                                        PUF04700
C     INDATA PART OF PROGRAM TERMINATED.                                PUF04710
 1175 CONTINUE                                                          PUF04720
C                                                                       PUF04730
C     CURRENT WINDDATA PRESENT.                                         PUF04740
C                                                                       PUF04750
C     OUTPRINTING CURRENT WINDDATA:                                     PUF04760
      WRITE(6,1161)  IWDASP ,ANGLE, SPEED                               PUF04770
C                                                                       PUF04780
```

```
C
C     CALCULTING WIND VELOCITY IN GRID UNITS: VGX,VGY
      VGX = SPEED*(COS(ANGLE*3.142/180)) / DELX
      VGY = SPEED*(SIN(ANGLE*3.142/180)) / DELY
C
C     RENAMING WIND AVERAGING TIME:WINDAV AS TAV:
      TAV = WINDAV
 1161 FORMAT(4H THE,I4,49H WINDDATASET IN THE CURRENT STAB.CLASS IS: ANG
     1LE=,I4,8H ,SPEED=,F4.1)
C
C     LOOP THRU BASIC ADVECTION STEPS WITH CURRENT WIND FIELD
C
      DO 5000   NN=1,NADPRW
C
C     JUMPING OVER "ZERO-SETTING" OF CONCENTRATION MATRIX : CHI , IF
C     "DOSE MODE" IS SPECIFIED IN PRIMDA.
      IF(ABC(8).EQ. DOSE ) GO TO 1256
C
      DO 1255 IG=1,ICOLS
      DO 1255 JG=1,JROWS
      DO 1255 KG=1,KPLANS
 1255 CHI(IG,JG,KG) = 0.0
C
 1256 CONTINUE
C
C     TIMECOUNTER:TOTTIM (SEC.)
      TOTTIM = TOTTIM + NTADV
C     SKIPPING RELEASE-SECTION IF SPECIFIED
      IF(TOTTIM .GT. NRELSE) GO TO 1250
C     TESTING IF RELEASE CONDITIONS ARE FULFILLED
      IF(MOD(TOTTIM,TAU) .NE. 0) GO TO 1250
C
C     LOOP THRU MULTIPLE SOURCES
      DO 1250 I2 = 1,NRMULT
C
C     INDIVIDUAL RELEASE CONTROL AS SPECIFIED IN SOURCE DATA:
C
      IF((TOTTIM.LT.STRTRL(I2)) .OR. (TOTTIM.GT.STOPRL(I2))) GO TO 1250
C     TOTAL NUMBER RELEASED FROM SOURCE(I2): TPUFFS(I2):
      TPUFFS(I2) = TPUFFS(I2) + 1
C
C     SHIFTING PUFF TABLE ONE POSITION TO THE RIGHT AND THEREBY
C     GIVING SPACE FOR ONE NEW PUFF:
C
      J=1
 1204 DO 1205 K=1,7
 1205 SHIFT(J+1,K) = PTABEL(I2,J,K)
      J = J + 1
```

```
      IF(J.GE.100) GO TO 8900
      IF(PTABEL(I2,J,1) .NE. 0) GO TO 1204
      DO 1210  L = 2,J
 1209 DO 1210 K = 1,7
 1210 PTABEL(I2,L,K) = SHIFT(L,K)
C
C     INSERTING NEW PUFF DATA IN PUFF TABLE AT J = 1
      PTABEL(I2,1,1) = TPUFFS(I2)
C     DOSE RELEASED WITH EACH PUFF: SPECIFIED SOURCE STRENGTH*SEC.
C     BETWEEN RELEASES
      PTABEL(I2,1,2) = SOURST(I2) * TAU
C
C     LOADING IN INITIAL SOURCE POSITIONS
      PTABEL(I2,1,3) = XSOURC(I2)
      PTABEL(I2,1,4) = YSOURC(I2)
C
C   TO AVOID NUMERICAL PROBLEMS IN ESTIMATING PLUME RISE,
C     SET SOHT(I2) (SOURCE HEIGHT) .GE. 1 METER.
      PTABEL(I2,1,5) =SOHT(I2)/DELZ
C     INITIAL SIZE OF PUFFS:
C     SIGMAXY SET TO 1 METER:
      PTABEL(I2,1,6) = 1
C     SIGMAZ SET TO 1 METER:
      PTABEL(I2,1,7) =1
C     END OF PUFF RELEASE SECTION.
 1250 CONTINUE
C
C     ADVECTION OF ALL PUFF CENTERS
C
C     ADVANCE OF PUFF CENTERS IN GRID UNITS (HORIZONTALLY)
      DGX = VGX* NTADV
      DGY = VGY* NTADV
C     TOTALLY TRAVELED  DISTANCE BY THE PUFFS IN METERS
C     DURING CURRENT BASIC ADVECTION STEP: DMS
      DMS = SQRT((DGX*DELX)**2  +  (DGY*DELY)**2)
C
C     ADVECTION SECTION FOR ALL EXISTING PUFFS:
C     LOOP THRU ALL SOURCES,COUNTING REMOVED PUFFS:LEAVE
      DO 1300    I2 = 1, NRMULT
      J = 1
C     SKIPPING SOURCE I2,IF THE LAST BORN PUFF HAS LEFT GRID
      IF(PTABEL(I2,1,1).EQ.0) GO TO 1300
 1260 PTBL3  = PTABEL(I2,J,3) + DGX
      PTBL4  = PTABEL(I2,J,4) + DGY
C
C
C     CALLING SUBROUTINE "SIGRIS" ,THEREBY ADDING DEVIATION INCREMENT
C     AND PLUME RISE INCREMENT TO PUFF TABLE:
```

```
C        PTABEL(I2,J,5):  Z-POSITION IN GRIDUNITS                              PUF05870
C        PTABEL(I2,J,6):  SIGMAXY IN METERS                                    PUF05880
C        PTABEL(I2,J,7):  SIGMAZ IN METERS                                     PUF05890
C                                                                              PUF05900
         CALL SIGRIS(PTABEL(I2,J,5),PTABEL(I2,J,6),PTABEL(I2,J,7))             PUF05910
C                                                                              PUF05920
C        INTRODUCING AN UPPER LIMIT FOR BUOYANCY CONVECTION: ZM.               PUF05940
         IF(.NOT.NOMXDP.AND.PTABEL(I2,J,5).GT.ZMG) PTABEL(I2,J,5) = ZMG        PUF05950
C                                                                              PUF05980
C        Z - POSITIONS IN GRIDUNITS: PTBL5                                     PUF05990
         PTBL5  = PTABEL(I2,J,5)                                               PUF06000
C                                                                              PUF06010
C        TESTING AND REMOVING PUFFS WHICH HAVE LEFT THE GRID:                  PUF06020
         IF(PTBL3.GT.XSB.AND.PTBL3.LT.XLB.AND.PTBL4.GT.YBB.AND.PTBL4.LE.YL     PUF06030
        1L.AND.PTBL5.LT.ZLB) GO TO 1290                                        PUF06040
C                                                                              PUF06050
C        REMOVE SECTION                                                        PUF06060
         LEAVE = LEAVE + 1                                                     PUF06070
         IF(PTABEL(I2,J+1,1) .EQ. 0) GO TO 1265                                PUF06080
C        REMOVING PUFF BORN AT SOURCE I2 WHICH IS NOT THE LONGEST LIVING:      PUF06090
C        LEFT JUSTIFICATION OF OLDER PUFFS:                                    PUF06100
         JJ = J + 1                                                            PUF06110
 1269    DO 1270  K = 1,7                                                      PUF06120
 1270    SHIFT(JJ,K) = PTABEL(I2,JJ,K)                                         PUF06130
         JJ = JJ + 1                                                           PUF06140
         IF(PTABEL(I2,JJ,1) .NE. 0)  GO TO 1269                                PUF06150
         SHIFT(JJ,1) = 0                                                       PUF06160
         JMAX = JJ                                                             PUF06170
C        COPY SHIFT BACK INTO PTABEL:                                          PUF06180
         NY7=JMAX-1
         DO 1275 JJ = J,NY7
         DO 1275 K=1,7                                                         PUF06200
 1275    PTABEL(I2,JJ,K) = SHIFT(JJ+1,K)                                       PUF06210
C                                                                              PUF06220
C        RETURNING TO INCREMENTAL PART WITHOUT INCREASE IN J:                  PUF06230
         GO TO 1260                                                            PUF06240
C                                                                              PUF06250
C        REMOVING LONGEST LIVING PUFF FROM SOURCE(I2):                         PUF06260
 1265    PTABEL(I2,J,1) = 0                                                    PUF06270
C        CONTINUING WITH NEXT SOURCE                                           PUF06280
         GO TO 1300                                                            PUF06290
C                                                                              PUF06300
C        REPLACING NEW PUFF POSITION IN PUFF TABLE                             PUF06330
 1290    PTABEL(I2,J,3) = PTBL3                                                PUF06340
         PTABEL(I2,J,4) = PTBL4                                                PUF06350
C                                                                              PUF06380
C        CALCULATING GRID CONCENTRATION IN EACH BASIC ADVECTION STEP           PUF06390
C                                                                              PUF06420
```

```
C      RENAMING ESSENTIAL PARAMETERS:                                   PUF06430
C      DOSE IN CURRENT PUFF:                                            PUF06440
       QI = PTABEL(I2,J,2)                                              PUF06450
C      SIGMA VALUES IN METERS:                                          PUF06460
       SIGMXY = PTABEL(I2,J,6)                                          PUF06470
       SIGMZ  = PTABEL(I2,J,7)                                          PUF06480
C                                                                       PUF06490
C      CALCULATING MAXIMUM CONCENTRATION IN EACH PUFF CENTER            PUF06510
C      (PUFF-CHI-CENTER) , IN DIMENSION: GRAM/M**3 :                    PUF06520
C      CONSTANT : (2*PHI)**(3/2)                                        PUF06530
       CONST  = 15.7496                                                 PUF06540
C                                                                       PUF06550
       PCHCEN =  QI/(CONST*SIGMZ*SIGMXY**2)                             PUF06560
C                                                                       PUF06570
C      SKIPPING SUMMATION SECTION IF CONCENTRATION IS TOO LOW
       IF(PCHCEN.LT.CHEMIN) GO TO 1500                                  PUF06590
C                                                                       PUF06600
C      CALCULATING MAXIMUM RADIUS OF INTEREST FOR EACH PUFF:            PUF06610
C      MAXIMUM PUFF RADIUS IN METERS:                                   PUF06620
       PFRMXY = SIGMXY * SQRT(-2.*ALOG(CHEMIN/PCHCEN))                  PUF06630
       PFRMZ  = PFRMXY*SIGMZ/SIGMXY                                     PUF06640
C                                                                       PUF06650
C      X-DIRECTION:                                                     PUF06660
       PUFRGX = PFRMXY/DELX                                             PUF06670
C      Y-DIRECTION:                                                     PUF06680
       PUFRGY = PFRMXY/DELY                                             PUF06690
C      Z-DIRECTION:                                                     PUF06700
       PUFRGZ = PFRMZ/DELZ                                              PUF06710
C                                                                       PUF06720
C      DETERMINING START AND STOP GRID POINTS FOR ACCUMULATION OF       PUF06730
C      THE PUFFS IN QUESTION:                                           PUF06740
C                                                                       PUF06750
       ISTRTX = PTBL3 - PUFRGX + 1                                      PUF06760
       ISTOPX = PTBL3 + PUFRGX                                          PUF06770
       ISTRTY = PTBL4 - PUFRGY + 1                                      PUF06780
       ISTOPY = PTBL4 + PUFRGY                                          PUF06790
       ISTRTZ = PTBL5 - PUFRGZ + 1                                      PUF06800
       ISTOPZ = PTBL5 + PUFRGZ                                          PUF06810
C                                                                       PUF06820
C      CONTROL FOR EXCEEDING GRID DIMENSIONS                            PUF06830
C                                                                       PUF06840
       IF(ISTRTX.LT.XSB) ISTRTX=XSB                                     PUF06850
       IF(ISTOPX.GT.XLB) ISTOPX=XLB                                     PUF06860
       IF(ISTRTY.LT.YSB) ISTRTY=YSB                                     PUF06870
       IF(ISTOPY.GT.YLB) ISTOPY=YLB                                     PUF06880
       IF(ISTRTZ.LT.ZSB) ISTRTZ=ZSB                                     PUF06890
       IF(ISTOPZ.GT.ZLB) ISTOPZ=ZLB                                     PUF06900
C                                                                       PUF06910
```

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C     UPPER LIMIT IN CASE OF SPECIFIED MIXING DEPTH:ZM
      IF(.NOT.NOMXDP   .AND. ISTOPZ .GT. ZMG ) ISTOPZ = ZMG                 PUF06940
      IF(ISTRTZ .GT.ISTOPZ) GO TO 1500                                      PUF06950
C                                                                           PUF06960
C     CALCULATE CONTRIBUTIONS TO SURROUNDING GRIDPOINTS                     PUF06970
C                                                                           PUF06990
C     PRELIMINAR CALCULATIONS:                                              PUF07000
C     SIGMAS IN GRIDUNITS:                                                  PUF07010
      SIGGX = SIGMXY/DELX                                                   PUF07020
                                                                            PUF07030
      SIGGY = SIGMXY/DELY                                                   PUF07040
      SIGGZ = SIGMZ /DELZ                                                   PUF07050
C                                                                           PUF07060
C     CALCULATING DENOMINATOR UNDER EXP-SIGN:                               PUF07070
      SIGGX2 = (SIGGX**2)*(-2)                                              PUF07080
      SIGGY2 = (SIGGY**2)*(-2)                                              PUF07090
      SIGGZ2 = (SIGGZ**2)*(-2)                                              PUF07100
C                                                                           PUF07110
C     LOOPING THRU ALL GRIDPOINTS OF INTEREST:                              PUF07130
C                                                                           PUF07140
      DO 1500  KG = ISTRTZ,ISTOPZ                                           PUF07150
      ZG2NEG = (KG-PTBL5)**2                                                PUF07160
      PCHI1  = PCHCEN * EXP(ZG2NEG/SIGGZ2)                                  PUF07170
      IF(GRRFLX) PCHI1 = PCHI1 + PCHCEN*REFLEC*EXP((<G+PTBL5)**2/SIGGZ2)PUF07180
      IF(NOMXDP) GO TO 1295                                                 PUF07190
      IF((PTBL5+PUFRGZ) .LT. ZMG) GO TO 1295                                PUF07200
      ZG2MX  = (KG+PTBL5-2*ZMG)**2                                          PUF07210
      PCHI1  = PCHI1 + PCHCEN*EXP(ZG2MX/SIGGZ2)                             PUF07220
 1295 DO 1500  IG = ISTRTX,ISTOPX                                           PUF07230
      XG2 = (IG-PTBL3)**2                                                   PUF07240
      DO 1500  JG = ISTRTY,ISTOPY                                           PUF07250
      YG2 = (JG-PTBL4)**2                                                   PUF07260
C                                                                           PUF07270
C     INDIVIDUAL PUFFS CONTRIBUTION : PCHI,GRAM/M**3                        PUF07280
C                                                                           PUF07290
      PCHI   = PCHI1 * EXP(XG2/SIGGX2 + YG2/SIGGY2)                         PUF07300
C                                                                           PUF07310
      IF(PCHI .LT. CHEMIN) GO TO 1500                                       PUF07320
C     ACCUMULATING IN GRIDPOINTS:                                           PUF07330
      CHI(IG+1,JG+1,KG+1) = CHI(IG+1,JG+1,KG+1) + PCHI                      PUF07340
C                                                                           PUF07350
 1500 CONTINUE                                                              PUF07360
C                                                                           PUF07370
C     END OF CONCENTRATION CALCULATIONS                                     PUF07380
C                                                                           PUF07410
C                                                                           PUF07440
C     ADVANCE IN PUFF TABLE (J) DURING BASIC ADVECTION STEP                 PUF07450
      J = J + 1                                                             PUF07460
```

```
      IF(PTABEL(I2,J,1) .NE. 0) GO TO 1260                              PUF07470
 1300 CONTINUE                                                          PUF07480
C     END OF ADVECTION SECTION                                          PUF07490
C                                                                       PUF07500
C                                                                       PUF07510
C                                                                       PUF07520
C***********************************************************************PUF07530
C*********************  OUTPRINT SECTION  ******************************PUF07540
C***********************************************************************PUF07550
C                                                                       PUF07560
C     SECTION FOR OUTPRINTING PUFF POSITIONS IN GRID.                   PUF07570
C                                                                       PUF07580
C                                                                       PUF07590
C     SKIPPING PUFF POSITION PLOT IF SPECIFIED:
C                                                                       PUF07610
C     TOTTIM TRUNCATED TO INTEGER NUMBER: ITOTIM.                       PUF07620
      ITOTIM = TOTTIM                                                   PUF07630
      IF(MOD(ITOTIM,MAPTIM) .NE. 0) GO TO 1600                          PUF07640
 1301 FORMAT(1H1)                                                       PUF07650
 1310 FORMAT(1H0,30X,'PLOT OF CURRENT PUFF POSITIONS',I6,
     &'SEC AFTER START OF RELEASE.')
 1320 FORMAT(1H0,30X,'TOTALLY',I6,'PUFFS HAVE BEEN RELEASED AND',I6,
     &'PUFFS HAVE LEFT THE GRID.')
 1325 FORMAT(1H+,24X,105A1)                                             PUF07700
 1326 FORMAT(1H ,17X,1H|,105A1)                                         PUF07710
 1327 FORMAT(1H ,I11,5X,2H +,105A1)                                     PUF07720
 1328 FORMAT(1H+,25X,105A1)                                             PUF07730
C                                                                       PUF07740
C                                                                       PUF07750
C     SUMMING UP ALL PUFFS RELEASED: SUMPUF                             PUF07770
      SUMPUF = 0                                                        PUF07780
      DO 1329 NPUF = 1,NRMULT                                           PUF07790
 1329 SUMPUF = SUMPUF + TPUFFS(NPUF)                                    PUF07800
C                                                                       PUF07810
      WRITE(6,1301)                                                     PUF07820
      WRITE(6,1310) ITOTIM                                              PUF07830
      WRITE(6,1)                                                        PUF07840
      WRITE(6,1320) SUMPUF,LEAVE                                        PUF07850
      WRITE(6,1)                                                        PUF07860
      WRITE(6,1)                                                        PUF07870
C                                                                       PUF07880
      IF(ICOLS .GT. 10) GO TO 1595                                      PUF07890
      WRITE(6,870) (I2,I2  =  XSB,XLB)                                  PUF07900
      WRITE(6,1)                                                        PUF07910
      WRITE(6,912) HORFRM                                               PUF07920
      WRITE(6,913) VERFRM,VERFRM                                        PUF07930
C                                                                       PUF07940
C     LOOPING THRU ALL Y-VALUES OF GRID, STARTING UPPERMOST:            PUF07950
```

```
      MAX = JROWS - 1
C     OUTER LOOP THRU INTEGER Y-VALUES:
      NY8=MAX+1
      DO 1350   NY9=1,NY8
      I2=NY9-1
      MAXMI2 = MAX - I2
      WRITE(6,1327) MAXMI2 , VERPLS
C
C     PLOTTING SOURCE POSITIONS
      K1 = 0
      DO 1330  J = 1,NRMULT
      IF(MAX-I2 .NE. YSOURC(J) )  GO TO 1330
C     NUMBER OF SOURCES IN MAINLINE: K1
      K1 = K1 + 1
      CALL ISPACE(XSOURC(J),J)
C     SOURCE POSITIONS IN EACH MAINLINE: XINT(K1)
      XINT(K1) = 10*XSOURC(J)
 1330 CONTINUE
C
C     LOOPING 9 LINES DOWN TO NEXT MAINLINE:
      DO 1345 NY10=1,10
      IDECI=NY10-1
      YLINE = 10*(MAX - I2) - IDECI  + 10
      IF(IDECI .GE. 1) WRITE(6,1326) VERFRM
C
C     SCANNING THRU WHOLE PUFF TABLE
      DO 1340 II = 1,NRMULT
      J = 0
 1335 J = J + 1
      IF(PTABEL(II,J,1) .EQ. 0) GO TO 1340
C     TRUNCATING Y-VALUE OF PUFF TO INTEGER:
      YINT = PTABEL(II,J,4)*10 + 10.5
C
C     PRINTING "*" IN GRIDFRAME IF X-POSITION OF PUF= NOT COINCIDE
C     WITH ONE OF THE SOURCE POSITIONS
      IF( (YINT .NE. YLINE) .OR. (IDECI .NE. 0) ) GO TO 1338
      COINCD = .FALSE.
C     INTEGER VALUE OF PUFFS X-POSITION: XINTPF
      XINTPF = PTABEL(II,J,3) * 10 + .5
      DO 1336 KK = 1,K1
 1336 IF(XINTPF .EQ. XINT(KK)) COINCD = .TRUE.
      IF(COINCD) GO TO 1335
      STRING(XINTPF + 1) = SN1
      GO TO 1335
C
 1338 IF(YINT .NE. YLINE) GO TO 1335
C     PRINTING PUFF POSITIONS BETWEEN Y-GRID LINES:
      XINTPF = PTABEL(II,J,3) * 10 + .5
```

```
      STRING(XINTPF + 1) = SN1                                          PUF08430
      GO TO 1335                                                        PUF08440
C                                                                       PUF08450
 1340 CONTINUE                                                          PUF08470
C     END OF PUFF TABLE LOOP.                                           PUF08480
C                                                                       PUF08490
C                                                                       PUF08500
      WRITE(6,1325) STRING                                              PUF08510
      DO 1342 NST = 1,105                                               PUF08520
 1342 STRING(NST)    = BL                                               PUF08530
C                                                                       PUF08540
 1345 CONTINUE                                                          PUF08550
C                                                                       PUF08570
C     RESET "SOURCE IN LINE COUNTER" XINT(KK)                           PUF08580
      DO 1349 KK=1,10                                                   PUF08590
 1349 XINT(KK) = -1                                                     PUF08600
C                                                                       PUF08610
 1350 CONTINUE                                                          PUF08620
C     END OF PUFF POSITION PLOT.                                        PUF08630
      WRITE(6,1)                                                        PUF08640
      WRITE(6,912) HORFRM                                               PUF08650
 1400 CONTINUE                                                          PUF08660
C                                                                       PUF08670
C     PLOTTING PUFFS IN "Y-Z FRAME";FOR COMMENTS REFER TO THE EQUI-     PUF08690
C     VALENT "Y-X FRAME" PLOTTING DESCRIBED ABOVE.                      PUF08700
C                                                                       PUF08710
      WRITE(6,1)                                                        PUF08720
      WRITE(6,1)                                                        PUF08730
      WRITE(6,1)                                                        PUF08740
  881 FORMAT(1H+,20X,I5,10H SOURCE(S))                                  PUF08750
      WRITE(6,871) (I2,I2=ZSB,ZLB)                                      PUF08760
      WRITE(6,1)                                                        PUF08770
C     HRFRMZ : STRING CONTAINING HORIZONTAL GRID FRAME                  PUF08780
      DO 1410 N = 1,105                                                 PUF08790
      VRFRMZ(N) = BL                                                    PUF08800
      VRPLSZ(N) = BL                                                    PUF08810
      PARENT(N) = BL                                                    PUF08820
 1410 HRFRMZ(N) = BL                                                    PUF08830
      NY11=MFZ*10
      DO 1418 IHFZ = MSZ,NY11,10                                        PUF08840
      NY12=IHFZ+4
      DO 1411 MN = IHFZ,NY12
 1411 HRFRMZ(MN) = SN4                                                  PUF08860
      HRFRMZ(IHFZ+5) = SN2                                              PUF08870
      NY13=IHFZ+6
      NY14=IHFZ+9
      DO 1416 MM=NY13,NY14
 1416 HRFRMZ(MM) = SN4                                                  PUF08890
```

```
 1418 CONTINUE
      WRITE(6,912) HRFRMZ                                               PUF08900
      PARENT(10*ZMG + 1) = SN6                                          PUF08910
      VRFRMZ(10*MFZ + 3) = SN5                                          PUF08920
      VRPLSZ(10*MFZ + 3) = SN3                                          PUF08930
      WRITE(6,1326) VRFRMZ                                              PUF08940
      WRITE(6,1326) VRFRMZ                                              PUF08950
      MAX = JROWS-1                                                     PUF08960
      DO 1445 NY15=1,JROWS                                              PUF08970
      I2=NY15-1
      MAXMI2 = MAX - I2                                                 PUF08980
      WRITE(6,1327) MAXMI2,VRPLSZ                                       PUF08990
      K1=0                                                              PUF09000
      DO 1430 J=1,NRMULT                                                PUF09010
      IF(MAX-I2 .NE. YSOURC(J)) GO TO 1430                              PUF09020
      K1 = K1+ 1                                                        PUF09030
 1430 CONTINUE                                                          PUF09040
C     WRITING NUMBER OF SOURCES IN EACH Y-GRIDLINE: VN SOURCE(S)        PUF09050
      IF(K1 .GT. 0) WRITE(6,881) K1                                     PUF09060
      DO 1445 NY16=1,10
      IDECI=NY16-1
      YLINE = 10*(MAX-I2) - IDECI +10                                   PUF09080
      IF(IDECI.GE.1) WRITE(6,1326) VRFRMZ                               PUF09090
C     ILLUSTRATING MIXING DEPTH IN Y-Z FRAME:
      IF(ZMG.GT.0) WRITE(6,1328) PARENT                                 PUF09110
      DO 1440 II = 1,NRMULT                                             PUF09120
      J=0                                                               PUF09130
 1435 J = J + 1                                                         PUF09140
      IF(PTABEL(II,J,1) .EQ. 0) GO TO 1440                              PUF09150
      YINT = PTABEL(II,J,4) *10 + 10.5                                  PUF09160
      IF(YINT .NE. YLINE) GO TO 1435                                    PUF09170
C                                                                       PUF09180
      ZINTPF = PTABEL(II,J,5)* 10 + .5                                  PUF09190
      STRING(ZINTPF + 1) = SN1                                          PUF09200
      GO TO 1435                                                        PUF09210
C                                                                       PUF09220
 1440 CONTINUE                                                          PUF09230
C                                                                       PUF09240
      WRITE(6,1325) STRING                                              PUF09250
      DO 1442 NST = 1,105                                               PUF09260
 1442 STRING(NST) = BL                                                  PUF09270
C                                                                       PUF09280
 1445 CONTINUE                                                          PUF09290
C                                                                       PUF09300
      WRITE(6,1)                                                        PUF09310
      WRITE(6,912) HRFRMZ                                               PUF09320
C                                                                       PUF09330
C     SECTION FOR OUTPRINTING GRID CONCENTRATIONS                       PUF09350
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C                                                                       PUF09360
C     SKIPPING CONCENTRATION PRINTING IF SPECIFIED IN PRIMDA.
      IF(ABC(9).EQ. NO ) GO TO 1600                                     PUF09380
C                                                                       PUF09390
 1510 FORMAT(1H0,49X,37H PRINT OF CURRENT GRID CONCENTRATIONS,/50X      PUF09410
     1,I6,29H SEC. AFTER START OF RELEASE.)                             PUF09420
 1520 FORMAT(1H0,49X,32H GRIDCONCENTRATION IN THE PLANE:,/51X,3HZ =F6.2 PUF09430
     1,25H METER ABOVE THE SURFACE.)                                    PUF09440
 1525 FORMAT(I11,8X,10E10.2)                                            PUF09450
C                                                                       PUF09460
      WRITE(6,1301)                                                     PUF09470
      WRITE(6,1510) ITOTIM                                              PUF09480
      WRITE(6,1)                                                        PUF09490
      WRITE(6,1)                                                        PUF09500
C                                                                       PUF09510
C     LOOP THRU ALL Z LEVELS                                            PUF09520
C                                                                       PUF09530
      DO 1550  KC=1,KPLANS                                              PUF09540
      DEMKM1 = DELZ*(KC-1)                                              PUF09550
      WRITE(6,1520) DEMKM1                                              PUF09560
      WRITE(6,1)                                                        PUF09570
      WRITE(6,870)  (IC,IC = XSB,XLB)                                   PUF09580
C     PRINTING EACH LINE IN CONCENTRATION TABLE:                        PUF09590
      DO 1560 JC = 1,JROWS                                              PUF09600
      JJC      = JROWS - JC                                             PUF09610
      JC1      = JJC + 1                                                PUF09620
      WRITE(6,1525) JJC,(CHI(IC,JC1,KC) , IC = MSX,MFX)                 PUF09630
      DO 1551 IC=MSX,MFX                                                PUF09640
 1551 CPLOT(IC,JC1)=CHI(IC,JC1,KC)                                      PUF09650
 1552 FORMAT(5X,10E10.2)                                                PUF09670
 1560 CONTINUE                                                          PUF09680
C
C     KC IS THE NO. OF LEVELS PRINTED...HERE CONTROLS WHICH
C     LEVELS ARE CONTOURED.
      IF (KC.EQ.1) CALL DRAW(CPLOT,10,17)
 1550 CONTINUE                                                          PUF09690
      WRITE(6,1)                                                        PUF09710
      WRITE(6,1)                                                        PUF09720
C                                                                       PUF09730
      GO TO 1600                                                        PUF09750
C                                                                       PUF09760
 1590 FORMAT(95H PUFF POSITION PLOT AND GRID CONCENTRATION PRINTING AR  PUF09770
     1E SUPPRESSED BECAUSE "ICOLS" EXCEED 10.)                          PUF09780
 1595 WRITE(6,1590)                                                     PUF09790
C                                                                       PUF09800
 1600 CONTINUE                                                          PUF09830
C     END OF GRID CONCENTRATION PRINTING SECTION                        PUF09840
C                                                                       PUF09870
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C      END OF OUTPRINT SECTION.                                         PUF09880
C                                                                       PUF09910
 5000 CONTINUE                                                          PUF09920
C      END OF ADVECTION STEPS DURING CURRENT WIND FIELD SPECIFICATION    PUF09930
C                                                                       PUF09940
C      END OF CALCULATION PART.                                         PUF09960
       I = I+2                                                          PUF09970
       IF(I.GE.14) GO TO 1135                                           PUF09980
C      RETURN FETCHING NEW ANGLE,SPEED:                                 PUF09990
       GO TO 1150                                                       PUF10000
C                                                                       PUF10020
C      OUTPUT DIAGNOSTICS :                                             PUF10030
 1000 FORMAT(37H X AND/OR Y COORDINATES OF SOURCE NR:,I5,12H IS OFF GRIDPUF10040
     1)                                                                 PUF10050
 1005 FORMAT(72H FORMAT ERROR IN SECOND WINDDA CARD:MISSING OR WRONG PL PUF10060
     1ACED #-CARACTER|)                                                 PUF10070
 1010 FORMAT(55H BAD SPECIFICATION OF PUFF RELEASE AND ADVECTION STEP,  PUF10080
     15H TAU=,I5,6X,7H NTADV=,I5)                                       PUF10090
 1015 FORMAT(60H BAD SPECIFICATION OF WINDAVERAGING TIME AND ADVECTION SPUF10100
     1TEP:,8H WINDAV=,I4,7X,7H NTADV=,I5)                               PUF10110
 1025 FORMAT(64H ERROR IN WINDDATA-SPECIFICATION OF:  *SPEED,"ANGLE, AFTPUF10120
     1ER THE:,I6,24H.STABILITY SPECIFICATION)                           PUF10130
 1030 FORMAT(86H MISSING STABILITY CLASS SPECIFICATION,THE LAST SPECIFI PUF10140
     1ED STABILITY CLASS NUMBER WAS,I6)                                 PUF10150
 1035 FORMAT(72H FORMAT ERROR IN SECOND PUFFDA-CARD: MISSING OR WRONG PLPUF10160
     1ACED #-CARACTER|)                                                 PUF10170
 1040 FORMAT(16H MISMATCH IN THE,I5,22H. SOURCE SPECIFICATION)          PUF10180
 1045 FORMAT(12H SOURCE NR:,I5,72H HAS MORE THN 100 CONTRIBUTING PUFFS  PUF10190
     1IN THE GRID.TAU MUST BE INCREASED.)                               PUF10200
 1050 FORMAT(72H FORMAT IN SECOND INTSDA-CARD; MISSING OR WRONG PL      PUF10210
     1ACED #-CARACTER|)                                                 PUF10220
 1055 FORMAT(41H ZM MUST BE AN INTEGER MULTIPLUM OF DELZ|)              PUF10230
 1060 FORMAT(47H MIXING LAYER DEPTH EXCEEDS Z DIMENSION OF GRID)
C                                                                       PUF10250
C                                                                       PUF10260
C                                                                       PUF10270
 8870 WRITE(6,1060)                                                     PUF10290
      GO TO 9999                                                        PUF10300
 8880 WRITE(6,1055)                                                     PUF10310
      GO TO 9999                                                        PUF10320
 8890 WRITE(6,1050)                                                     PUF10330
      GO TO 9999                                                        PUF10340
 8900 WRITE(6,1045) I                                                   PUF10350
      GO TO 9999                                                        PUF10360
 8910 WRITE(6,1040) I                                                   PUF10370
      GO TO 9999                                                        PUF10380
 8920 WRITE(6,1035)                                                     PUF10390
      GO TO 9999                                                        PUF10400
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 8930 WRITE(6,1140)                                                    PUF10410
      GO TO 9999                                                       PUF10420
 8940 NRM1   = NRSTAB - 1                                              PUF10430
      WRITE(6,1030) NRM1                                               PUF10440
      GO TO 9999                                                       PUF10450
 8950 WRITE(6,1025) NRSTAB                                             PUF10460
      GO TO 9999                                                       PUF10470
 8970 WRITE(6,1015) WINDAV,NTADV                                       PUF10480
      GO TO 9999                                                       PUF10490
 8980 WRITE(6,1010) TAU,NTADV                                          PUF10500
      GO TO 9999                                                       PUF10510
 8990 WRITE(6,1005)                                                    PUF10520
      GO TO 9999                                                       PUF10530
 9000 WRITE(6,1000) I                                                  PUF10540
C                                                                      PUF10550
 9999 CONTINUE                                                         PUF1A160
      CALL EFRAME
      STOP                                                             PUF10570
      END                                                              PUF10580
C                                                                      PUF10590
C                                                                      PUF10600
C                                                                      PUF10610
C                                                                      PUF10640
C                                                                      PUF10650
C                                                                      PUF10660
      SUBROUTINE SIGRIS(HGN,SIGXY,SIGZ)                                PUF10690
C                                                                      PUF10700
C     THE SUBROUTINE "SIGRIS" (SIGMA-RISE) CALCULATES THE INCREMENT    PUF10710
C     IN SIGMA-XY AND SIGMA-Z DURING EACH BASIC ADVECTION STEP.        PUF10720
C     FURTHER, THE SUBROUTINE ESTIMATES PLUMERISE ASSOCIATED WITH      PUF10730
C     BOUYANCY IN THE EFFLUXES.                                        PUF10740
C                                                                      PUF10750
C     FOR Z-COORDINATES OF PUFFS: HEIGHT , GRID UNITS(N) : HGN         PUF10760
C                                                                      PUF10780
      COMMON HEATFX(25),I2,DMS,POINT,INTENS(14),STABPA,FBUFLX          PUF10790
     1,UNN, CONST1,DELZ                                                PUF10800
      INTEGER POINT
      REAL INTENS
C     CALCULATING GROWTH RATES FOR SIGMAS; DSIGDS                      PUF10810
C     DEFINING EXPERIMENTAL FITTING CONSTANT: FITCST                   PUF10820
      FITCST = 2.0                                                     PUF10830
      DSIGDS = .22 * INTENS(POINT)                                     PUF10850
      DSIGDS = DSIGDS * FITCST                                         PUF10860
      SIGXY  = SIGXY + DSIGDS * DMS                                    PUF10870
      SIGZ   = SIGZ  + DSIGDS * DMS                                    PUF10880
C                                                                      PUF10890
C     CALCULATING PLUME-RISE INCREMENT:                                PUF10900
C                                                                      PUF10910
```

```
C     FI : BUOYANT FLUX FROM SOURCE I
C     AFTER BRIGGS:
C     F = 8.9 < M**4/SEC**3> * Q < MWATT >
C     HEATFX(I2) UNITS ARE KW
      FI = 8.9 * 0.001 * HEATFX(I2)
C
      IF(STABPA.LE.0.0) GO TO 2501
C     MAXIMUM PLUME LIFT IN STABLE ATMOSPHERE:HSMAX.
      HSMAXG = 2.9*(FI/(UNN*STABPA))**(1./3) / DELZ
 2501 CONTINUE
C
C     CALCULATING PLUME HEIGHT AFTER FILFILLED ADVECTION STEP
C     HGRID(N+1) : HGNP1.
      HGNP1 = HGN + CONST1*SQRT(FI/HGN)/((DELZ *UNN)**1.5)*DMS
      IF(STABPA.LE.0.0) GO TO 2510
      IF(HGNP1.GT.HSMAXG) GO TO 2520
 2510 HGN = HGNP1
 2520 CONTINUE
      RETURN
      END
C
C
C
C
      SUBROUTINE ISPACE(ITENFT,INR)
C
C     THE SUBROUTINE "ISPACE" MAKES VARIABLE TABULATING POSSIBLE
C     IN CONNECTION WITH FRAMEPLOTS.
C
C     ITENFT: NUMBER OF TEN SPACES,THE FIGURE IN QUESTION HAS TO
C             BE MOVED RIGHTMOST.
C
C     INR    : INTEGER NUMBER TO BE PRINTED.
C
   10 FORMAT(1H+,19X,I6)
   20 FORMAT(1H+,29X,I6)
   30 FORMAT(1H+,39X,I6)
   40 FORMAT(1H+,49X,I6)
   50 FORMAT(1H+,59X,I6)
   60 FORMAT(1H+,69X,I6)
   70 FORMAT(1H+,79X,I6)
   80 FORMAT(1H+,89X,I6)
   90 FORMAT(1H+,99X,I6)
  100 FORMAT(1H+,109X,I6)
C
C
      IF(ITENFT.NE.0) GO TO 1
      WRITE(6,10) INR
```

```
      RETURN                                                            PUF11430
    1 IF(ITENFT.NE.1) GO TO 2                                           PUF11440
      WRITE(6,20) INR                                                   PUF11450
      RETURN                                                            PUF11460
    2 IF(ITENFT.NE.2) GO TO 3                                           PUF11470
      WRITE(6,30) INR                                                   PUF11480
      RETURN                                                            PUF11490
    3 IF(ITENFT.NE.3) GO TO  4                                          PUF11500
      WRITE(6,40) INR                                                   PUF11510
      RETURN                                                            PUF11520
    4 IF(ITENFT.NE.4) GO TO  5                                          PUF11530
      WRITE(6,50) INR                                                   PUF11540
      RETURN                                                            PUF11550
    5 IF(ITENFT.NE.5) GO TO  6                                          PUF11560
      WRITE (6,60) INR                                                  PUF11570
      RETURN                                                            PUF11580
    6 IF(ITENFT.NE.6) GO TO  7                                          PUF11590
      WRITE(6,70) INR                                                   PUF11600
      RETURN                                                            PUF11610
    7 IF(ITENFT.NE.7)GO TO   8                                          PUF11620
      WRITE(6,80) INR                                                   PUF11630
      RETURN                                                            PUF11640
    8 IF(ITENFT.NE.8) GO TO  9                                          PUF11650
      WRITE(6,90) INR                                                   PUF11660
      RETURN                                                            PUF11670
    9 IF(ITENFT.NE.9) GO TO 1000                                        PUF11680
      WRITE(6,100) INR                                                  PUF11690
 1000 RETURN                                                            PUF11700
      END                                                               PUF11710
C                                                                       PUF11720
C
C
      SUBROUTINE DRAW (A,M,N)
C
C    THIS SUBROUTINE CONVERTS THE GRID CONCENTRATIONS TO LOG VALUES
C    THEN SMOOTHES AND CONTOURES THE PUFF ARRAY...
C                                                                       PUF11740
      DIMENSION A(M,N)
C
C     A IS THE ARRAY TO BE SMOOTHED AND CONTOURED
C     M,N IS THE DIMENSION OF ARRAY A
C
      DO 1553 JC=1,N
      JJC=N-JC
      JC1=JJC+1
      DO 1554 IC=1,M
      IF(A( IC,JC1).LT. .1E-12) A(IC,JC1)=0.0
      A( IC,JC1)=A(IC,JC1)*1.E13
```

```
      IF(A(IC,JC1).EQ.0.0) GO TO 1554
      A(IC,JC1)=ALOG10(A(IC,JC1))
 1554 CONTINUE
 1553 WRITE(6,1555) (A(IC,JC1),IC=1,M)
 1555 FORMAT(5X,10E10.2)
C     SMOOTH ARRAY
      MM1=M-1
      NM1=N-1
      DO 200 J=1,N
      TEMP=A(1,J)
      DO 100 I=2,MM1
      TEMP1=A(I,J)
      A(I,J)=.20*(TEMP+3.*TEMP1+A(I+1,J))
      TEMP=TEMP1
  100 CONTINUE
  200 CONTINUE
      DO 400 I=1,M
      TEMP=A(I,1)
      DO 300 J=2,NM1
      TEMP1=A(I,J)
      A(I,J)=.20*(TEMP+3.*TEMP1+A(I,J+1))
      TEMP=TEMP1
  300 CONTINUE
  400 CONTINUE
      DO 1559 J=1,17
 1559 WRITE (6,1555) (A(I,J),I=1,10)
      CALL SET (.1,.31,.2,.58,0.,1.,0.,1.,1)
      CALL CONREC(A,10,10,17,0.,0.,1.,-1,-1,0)
      CALL TICK4(5,8,5,8)
      CALL PERIM(9,0,16,0)
      CALL FRAME
      RETURN
      END
C
C
C
C
      SUBROUTINE RSPACE(ITENFT,RNR)
C
C     THIS SUBROUTINE HAS THE SAME PURPOSE FOR REAL FIGURES, AS
C     ISPACE HAS FOR INTEGER FIGURES.
C
C     RNR    : REAL NUMBER TO BE PRINTED.
C
   10 FORMAT(1H+,19X,F6.1)
   20 FORMAT(1H+,29X,F6.1)
   30 FORMAT(1H+,39X,F6.1)
   40 FORMAT(1H+,49X,F6.1)
```

```
   50 FORMAT(1H+,59X,F6.1)                                              PUF11870
   60 FORMAT(1H+,69X,F6.1)                                              PUF11880
   70 FORMAT(1H+,79X,F6.1)                                              PUF11890
   80 FORMAT(1H+,89X,F6.1)                                              PUF11900
   90 FORMAT(1H+,99X,F6.1)                                              PUF11910
  100 FORMAT(1H+,109X,F6.1)                                             PUF11920
C                                                                       PUF11930
C                                                                       PUF11940
      IF(ITENFT.NE.0) GO TO 1                                           PUF11950
      WRITE(6,10) RNR                                                   PUF11960
      RETURN                                                            PUF11970
    1 IF(ITENFT.NE.1) GO TO 2                                           PUF11980
      WRITE(6,20) RNR                                                   PUF11990
      RETURN                                                            PUF12000
    2 IF(ITENFT.NE.2) GO TO 3                                           PUF12010
      WRITE(6,30) RNR                                                   PUF12020
      RETURN                                                            PUF12030
    3 IF(ITENFT.NE.3) GO TO 4                                           PUF12040
      WRITE(6,40) RNR                                                   PUF12050
      RETURN                                                            PUF12060
    4 IF(ITENFT.NE.4) GO TO 5                                           PUF12070
      WRITE(6,50) RNR                                                   PUF12080
      RETURN                                                            PUF12090
    5 IF(ITENFT.NE.5) GO TO 6                                           PUF12100
      WRITE(6,60) RNR                                                   PUF12110
      RETURN                                                            PUF12120
    6 IF(ITENFT.NE.6) GO TO 7                                           PUF12130
      WRITE(6,70) RNR                                                   PUF12140
      RETURN                                                            PUF12150
    7 IF(ITENFT.NE.7) GO TO 8                                           PUF12160
      WRITE(6,80) RNR                                                   PUF12170
      RETURN                                                            PUF12180
    8 IF(ITENFT.NE.8) GO TO 9                                           PUF12190
      WRITE(6,90) RNR                                                   PUF12200
      RETURN                                                            PUF12210
    9 IF(ITENFT.NE.9) GO TO 1000                                        PUF12220
      WRITE(6,10) RNR                                                   PUF12230
 1000 RETURN                                                            PUF12240
      END                                                               PUF12250
//GO.FT01F001 DD *
   12 3600     0    10    17     4     1
 3600   40    90
PRIMDATA SEPT 29 81
    217.50     435.00      40.00 1.000E-13     1.0000
YES
YES
YES
YES
```

```
INST
//GO.FT02F001 DD UNIT=SYSDA,DISP=(OLD,DELETE),DSN=&FT02
//GO.FT03F001 DD *
STABILITY-DATA, SEPT 29 81
     1.0000
      80.00
//GO.FT04F001 DD *
INDIVIDUAL SOURCE DATA
#01#
     1     2     0     0 3600    6.04         15.07       4.0
//GO.SYSIN DD *
INTENSITY-DATA, SEPT 29 81
# 5#
.2500.1000.0500.0100.0300
```

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